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J. E. THOMSON, *Director, Geological Branch*

Geology of

Townships 31 and 30, Ranges 20 and 19

District of Algoma

By

L. D. AYRES

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Geological Maps and Chart
(back pocket)

Map 2138 (coloured)—Townships 31 and 30, Range 19, District of Algoma. Scale, 1 inch to ½ mile.

Map 2139 (coloured)—Townships 31 and 30, Range 20, District of Algoma. Scale, 1 inch to ½ mile.

Chart A—Figures 2, 8, 9 and 10.

ABSTRACT

The map-area comprises 150 square miles on the east shore of Lake Superior within Lake Superior Provincial Park, and is 85 miles north of Sault Ste. Marie.

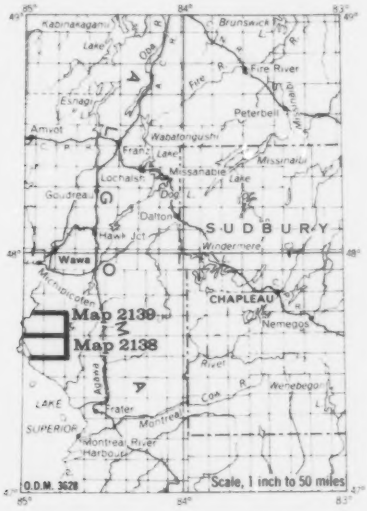


Figure 1 — Key map showing location of map-area.

A pre-Keweenawan, probably Archean, metavolcanic sequence (comprising a lower 4,775-foot thick mafic metavolcanic formation, a middle 1,600-foot thick, dominantly pyroclastic, felsic metavolcanic formation, and an upper 4,450-foot thick mafic metavolcanic formation) intertongues southwestward with 9,500 feet of metagreywacke and metasiltstone which are temporally equivalent to the metavolcanic sequence.

Pre-Keweenawan intrusions range in composition from ultramafic to granite and syenite, and underlie about fifty percent of the map-area. Intrusion began during volcanism and continued intermittently until late in the tectonic cycle. Composite granitic batholiths border the metavolcanic-metasedimentary assemblage on the northeast and southwest. The Gamitagama Lake Complex, a calc-alkaline stock which ranges in composition from olivine gabbro to syenite, and nine related granitic stocks are the youngest pre-Keweenawan intrusions.

The metavolcanic-metasedimentary sequence was isoclinally folded and regionally metamorphosed to the greenschist and almandine amphibolite facies prior to intrusion of the Gamitagama Lake Complex. The complex caused cross folding.

About 2,000 feet of Middle Keweenawan basalt, rhyolite, and conglomerate unconformably overlie earlier granitic rocks and are older than many of the Keweenawan diabase dikes. The dikes form a northeast-trending and two northwest-trending sets and were intruded by Keweenawan(?) alkalic syenite. About 600 feet of Cambrian Jacobsville Sandstone is in fault contact with older formations.

Most faults trend north, and the latest fault movement was post-Precambrian.

Concentrations of copper, nickel, and gold are associated with the Gamitagama Lake Complex: primary pyrrhotite-pentlandite-chalcopyrite segregations occur in pyroxene gabbro and diorite; gold-bearing quartz veins occur in a sheared quartz monzonite dike within gabbro; and chalcopyrite occurs in quartz veins and mafic metavolcanics near a shear zone in the contact metamorphic aureole. Chalcopyrite, manganite, and hematite occur in fault zones in other parts of the area. Iron formations have a maximum thickness of 350 feet but have a low iron content.

Geology of

Townships 31 and 30, Ranges 20 and 19

District of Algoma

by

L. D. Ayres[1]

INTRODUCTION

Townships 31 and 30, Ranges 20 and 19 are in Lake Superior Provincial Park in the District of Algoma, and Lake Superior is the western boundary of the map-area. The Ryan Mineral Location, a 2-mile by 5-mile patented area along the shore of Lake Superior, west of Township 31, Range 19, is included in the map-area but is not part of the provincial park. The Range 20–Range 19 boundary is 118 miles[2] by road (the Trans-Canada Highway, No. 17) north of Sault Ste. Marie and 27 miles south of Wawa.

Mineral exploration has been carried out intermittently since 1846, but prospecting has been prohibited since 1956. There is no recorded mineral production.

Acknowledgments. Assistance in the field was provided by W. T. Piche, J. M. Harvey, G. C. Lambert, and J. D. Sheppard in 1961; by P. F. Joseph, W. R. Code, G. L. Farr, D. Mann, and T. M. Seward in 1962; and by V. A. Jones and B. Mottershead in May, 1963. Mr. Piche and Mr. Joseph, as senior assistants, were responsible for part of the geological mapping. Laboratory assistance was provided by C. E. Blackburn and J. Ramsden.

R. Bowers, a pilot for White River Air Services Limited in Wawa, was very helpful during the 1961 and 1962 field seasons. In 1961, R. Kopich of Belco Timber Company permitted the field party to use the company's private road between Highway 17 and Gargantua Harbour on Lake Superior. In 1962, a camp site was provided by E. M. Montgomery, the chief ranger of Lake Superior Provincial Park.

G. S. Gilbert of The Algoma Steel Corporation Limited, W. D. Sutherland of Coutu Gold Mines Limited, A. M. Clarke of Falconbridge Nickel Mines Limited, D. E. Smith of Franc. R. Joubin and Associates, and J. C. Frantz and R. D. Westervelt of the Keevil Mining Group Limited kindly supplied the author with geological information on various parts of the map-area.

Part of the laboratory work was carried out by the author at the Department of Geology, Princeton University.

---

[1]Graduate student, Princeton University, Princeton, N.J., U.S.A. 1961, 1962. Manuscript received by Chief Geologist 24 June 1966.

[2]Reconstruction of part of Highway 17 north of Sault Ste. Marie would shorten this distance.

Townships 31 and 30

Means of Access. Highway 17 bisects Township 31, Ranges 20 and 19. Two roads and two bulldozed diamond-drill trails provide limited access east of the highway. Access west of the highway is restricted to several trails and a private road to Gargantua Harbour. From Gargantua Harbour old logging haulage roads extend northward to the central part of the Ryan Mineral Location.

Streams are small with many rapids, and canoe travel is difficult.

On Lake Superior, boats can anchor safely only at Gargantua Harbour and at Indian Harbour, although, in calm weather, small boats may be beached at several other places along the shore. Several trails extend inland from Lake Superior. The Provincial Parks Act prohibits landing of float-equipped planes except at certain designated lakes.

The Algoma Central Railway[1] is 12 miles east of the map-area.

Field Methods. Townships 31 and 30, Range 19, and the Ryan Mineral Location were mapped in 1961, and Townships 31 and 30, and part of Township 29, Range 20 (Fig. 9 on Chart A, back pocket) were mapped in 1962. Mineral prospects were examined in May 1963.

The basemap was supplied by the Cartographic Unit of the Ontario Department of Mines; it had been prepared from Forest Resources Inventory maps which were compiled by the Ont. Dept. of Lands and Forests from air photographs taken in 1949. During the survey minor corrections were made to this basemap by the author. The township boundaries were surveyed in 1901 and 1902, but no survey posts were found.

Field mapping was carried out on a scale of 1 inch to ¼ mile. Geological data were obtained by traverses along shorelines and streams, and, in forested areas, by pace and compass traverses with a spacing ranging from 1,000 to 1,500 feet. The data were plotted on acetate sheets attached to air photographs and were later transferred to the basemap by means of a double reflecting projector. Because the published geological maps (No. 2138 and No. 2139, back pocket) have a scale of 1 inch to ½ mile, some of the geological information has been generalized. Information provided by mining companies was utilized in compilation of the maps.

Uncoloured preliminary geological maps of Townships 31 and 30, Range 19 (P.128, P.129) and of Townships 31 and 30, Range 20 (P.174, P.175) on the scale of 1 inch to ¼ mile were published in 1961 and 1963 respectively.

History. As an incentive to build a railway from Sault Ste. Marie to Hearst, the Algoma Central and Hudson Bay Railway[1] was given, in 1900, a large land grant which included Townships 31 and 30, Ranges 20 and 19. In 1940, following a controversy over taxes, it reconveyed some of its land, including these four townships, to the crown.

Between 1900 and 1940 prospecting and staking were controlled by the Railway, and, when the land was returned to the crown, staking was prohibited until 11 May 1942. Lake Superior Provincial Park was created on 13 January 1944, and the area was closed for staking about eight months prior to this date. The park was opened for controlled staking on 19 June 1945, and, prior to the final

[1]Name changed in 1965 from Algoma Central and Hudson Bay Railway to Algoma Central Railway.

recording of a claim, the staker was required to prove to the satisfaction of a Departmental inspector that the claim, or group of claims, contained valuable mineral in place. These regulations remained in effect until 22 August 1956 when all prospecting and staking in provincial parks were prohibited.

Natural Resources. The map-area is in the Algoma Section of the Great Lakes–St. Lawrence Forest Region (Rowe 1959). Sugar maple, yellow birch, white spruce, balsam fir, eastern cedar, mountain ash, and alder are the dominant tree species, but minor red pine, white pine, jackpine, black spruce, white birch, poplar, and tamarack are present. Maple, mountain ash, and yellow birch commonly grow on ridges and hills, and white spruce and balsam grow on the lower slopes and in valleys. However, near Lake Superior, maple and birch are rare, and spruce and balsam are the dominant tree species. Alder and cedar occur in low, swampy areas; jackpine was found only near Lake Superior. Some hardwood was cut from the Ryan Mineral Location in the early part of this century.

Many lakes and streams are stocked with speckled trout, and perch and pike occur in several lakes. Commercial fishermen formerly operated from Indian Harbour and Gargantua Harbour.

Bear, beaver, chipmunk, fisher, mink, moose, muskrat, otter, porcupine, rabbit, red fox, squirrel, and weasel have been observed in the map-area.

Streams are swift with many rapids and falls, but the volume of water is generally too small and too variable for water power purposes.

Inhabitants. Administrative headquarters for Lake Superior Provincial Park are at the south end of Red Rock Lake in Township 30, Range 20. The Ontario Department of Lands and Forests also has a temporary camp at the junction of Highway 17 and the road to Mijinemungshing Lake. Belco Timber Company has a camp at Gargantua Harbour.

Physiography. Elevations in the map-area range from 601.6 feet, the low water datum of Lake Superior, to about 2,100 feet. The highest elevation is on a north-trending diorite ridge in Townships 30 and 29, Range 19. The maximum local relief is 800 feet, and local relief is commonly greater near Lake Superior than inland. In general, there is a gradual increase in elevation from Lake Superior inland, but sheer fault scarps or fault-line scarps as much as 400 feet high occur along part of the Lake Superior shore in Township 31, Range 20. Elevations near Lake Superior were taken from Ontario Department of Lands and Forests map, Aerial Survey, Lake Superior Coast, Batchawana Bay to Michipicoten Harbour, Sheet 4, 1931.

In the eastern part of the area, the crests of many hills have an elevation of 1,600 feet and may represent a former erosion surface of unknown age.

Ambrose (1964, p.818) has postulated that "the present exposed bedrock topography over much if not all of the Precambrian Shield [of North America] was developed in pre-Paleozoic time . . . ." and that the present topography is an exhumed paleoplain. In the map-area, however, much of the bedrock topography is controlled by post-Precambrian faults (p.62).

Townships 31 and 30

The major drainage systems, Red Rock River, Gargantua River, and Baldhead River, are less than 20 miles long, and only the Baldhead River drainage basin extends beyond the map-area. These rivers and many of the smaller streams locally occupy fault-line valleys. Radial drainage is poorly developed on the Gamitagama Lake Complex in Townships 30 and 29, Ranges 20 and 19.

Outcrop density is variable. A high outcrop density and good exposures are found near Lake Superior where many of the hilltops are bare of vegetation. Inland the hills support a thick forest growth, and bedrock is poorly exposed; many outcrop areas shown on the geological maps (No. 2138 and No. 2139) are mantled by a thin vegetal cover through which project small, scattered, moss-covered knobs of outcrop. On some hills bedrock is almost completely buried by glacial deposits, which also cover most of the bedrock in valleys. Except near Lake Superior, outcrop is rare along lake shores.

Most rock types are about equally well exposed, but diabase dikes are commonly more resistant to erosion than their country rocks and form linear ridges, although locally the dikes have been eroded to form linear valleys.

Previous Geological Work. The earliest geological work in the map-area was by Bigsby (1824a, p.12, 13; p.237-239) and Bayfield (1829, p.13) and was a by-product of hydrographic surveys along the shore of Lake Superior. Other brief descriptions of exposures near Lake Superior were given by Logan (1846, p.24, 25, 31; 1847), Agassiz (1850), Herrick *et al.* (1887), Bell (1876, p.218, 219; and G.S.C. Map 159), and Coleman (1899).

In 1898, subsequent to the discovery of gold at Missanabie in 1896 and at Wawa in 1897, Bell (1898) outlined the metavolcanic-metasedimentary belt in which the map-area is located. In 1905, Coleman (1906, p.176, 193, 194) examined iron formation in Townships 31 and 30, Range 20, and a map of these townships is included with his report. Pleistocene beaches were measured by Stanley (1932) in 1931.

The area immediately north of the map-area was mapped by Matheson (1933), but the geological map was never published.

The Algoma Central Railway has issued a geological map (A.C.R. 1964a), a Pleistocene geology map (A.C.R. 1964b), a photo interpretation map (A.C.R. 1964c), and a photo mozaic (A.C.R. 1964d), which include the map-area.

O.D.M.–G.S.C. aeromagnetic map 2190G provides aeromagnetic coverage.

GENERAL GEOLOGY

A brief explanation of the petrographic and stratigraphic terminology used in the report is given in the appendix.

Rock units in the map-area form four groups: pre-Keweenawan, Keweenawan, Paleozoic, and Cenozoic, which are separated by major hiatuses (see Table of Formations, opposite).

Pre-Keweenawan, metavolcanic formations, which from oldest to youngest are the 4,775-foot thick lower mafic metavolcanics, the 1,600-foot thick felsic

TABLE OF FORMATIONS

CENOZOIC:

RECENT:
Organic mud; lacustrine and fluvial clay, silt, and sand; beach sand and gravel.

PLEISTOCENE:
Drift; fluvial sand and gravel; beach sand and gravel.

Unconformity

PALEOZOIC:

Lower and Middle Cambrian:
Jacobsville Sandstone.

Fault Contact

PRECAMBRIAN:

KEWEENAWAN:

UPPER-MIDDLE TO UPPER KEWEENAWAN:
Alkalic syenite.

Intrusive Contact

Diabase and granophyre.

Intrusive Contact?

MIDDLE KEWEENAWAN:
Rhyolite member.
Upper basalt member.
Upper conglomerate member.
Middle basalt member.
Lower conglomerate member.
Lower basalt member.

Unconformity

PRE-KEWEENAWAN:

Unmetamorphosed ultramafic dikes.[1]

Gamitagama Lake Complex:

Syenite and monzonite.

Quartz monzonite and granodiorite. } *equivalent in age* { *The following are equivalent in age to one unit of the Gamitagama Lake Complex, but are not part of the Complex.*

Quartz monzonite, granodiorite, and granite stocks:
Baldhead River Quartz Monzonite.
Bussineau Lake Quartz Monzonite.
Belanger Lake stocks.
Fife Lake Granite.
Chaillon Lake Quartz Monzonite.
Gravel Lake stock.
Rathwell Lake stock.
Kasubeck Creek Granodiorite.

Porphyritic potassic granite dikes.

Hybrid diorite, tonalite, syenodiorite, and trondhjemite.

Gabbro and diorite.

Intrusive Contact?

Batholithic trondhjemite, granodiorite, quartz monzonite, granite, and syenite. (In Range 19) } = { Ryan Migmatite: Metasedimentary formation plus batholithic granitic rocks.

Intrusive Contact

Gargantua Harbour Porphyritic Granodiorite.
Potassic granitic sills and dikes.[2]

Intrusive Contact?

Rabbit Blanket Lake Trondhjemite.[2] } = = { Mijinemungshing Lake Trondhjemite.[2]
Sodic granitic sills and dikes.[2]

Intrusive Contact?

Metagabbro and metamorphosed ultramafic rocks.

Intrusive Contact

Upper mafic metavolcanic formation: mafic metavolcanics, felsic metavolcanics, metagreywacke, metaconglomerate, metamorphosed iron formation.

Felsic metavolcanic formation: felsic metavolcanics, mafic metavolcanics, metamorphosed iron formation, metagreywacke, metaconglomerate.

Lower mafic metavolcanic formation: mafic metavolcanics, felsic metavolcanics, metamorphosed iron formation, metagreywacke, metaconglomerate.

= { Metasedimentary formation: metagreywacke, metasiltstone, metaconglomerate, iron-rich metasediments and metamorphosed iron formation, mafic metavolcanics, felsic metavolcanics.

---

[1] Relationship to Gamitagama Lake Complex is unknown.
[2] Relative age probably correct, but relationship to Gargantua Harbour Porphyritic Granodiorite is unknown.

metavolcanics, and the 4,450-foot thick upper mafic metavolcanics, underlie the northeast part of the map-area. The metavolcanics interfinger southwestward and possibly eastward with 9,500 feet of metagreywacke and metasiltstone (Fig. 2 on Chart A, back pocket; Fig. 3, p.18). Mafic metavolcanics are dominantly flows while felsic metavolcanics are commonly pyroclastic in origin. Metamorphosed iron formation is present in both metavolcanics and metasediments in the lower part of the sequence. Neither the base nor top of the sequence is exposed.

Pre-Keweenawan intrusive rocks underlie about fifty percent of the area. Intrusion began during volcanism and continued until late in the tectonic cycle. Composite granitic batholiths border the metavolcanic-metasedimentary sequence on the northeast and southwest, and part of the southwestern batholith is a migmatite composed of metasedimentary and granitic rocks. The earliest granitic rocks are sodic, but later granitic and syenitic intrusions are more potassic. The Gamitagama Lake Complex is a late, partly differentiated and partly hybridized, calc-alkaline stock which may be post-orogenic. Age relationships among many of the intrusive rocks are uncertain because of restricted distribution.

The sedimentary-volcanic sequence was isoclinally folded and, in conjunction with some of the intrusive rocks, was subjected to progressive regional metamorphism and to superimposed contact metamorphism.

About 2,000 feet of Middle Keweenawan basalt, conglomerate, and rhyolite unconformably overlie pre-Keweenawan rocks. Diabase dikes form a northeast-trending and two northwest-trending sets which underlie two percent of the map-area. Many of the dikes appear to be younger than the Middle Keweenawan volcanic rocks. Two alkalic syenite dikes intrude diabase and may be related to alkalic intrusions near Chapleau, Wawa, or Coldwell (Kerr 1910; Parsons 1961).

The Paleozoic is represented by 600 feet of Lower and Middle Cambrian Jacobsville Sandstone.

No pre-orogenic or orogenic faults were recognized although they must be present. The latest movement on most of the faults is Keweenawan or younger, but some of these faults may have originated during orogeny.

Cenozoic deposits are widespread but are commonly thin.

Pre-Keweenawan

MAFIC METAVOLCANICS

Mafic metavolcanics in the map-area form two distinct formations which are herein referred to as the lower mafic metavolcanic formation, and the upper mafic metavolcanic formation; in most parts of the area these are separated by a felsic metavolcanic formation. Mafic metavolcanics are also found as rare thin lenses in other formations (Fig. 2, Fig. 9, on Chart A, back pocket).

The lower mafic metavolcanic formation has a maximum thickness of 4,775 feet in the centre of Township 30, Range 20, but the base of the formation was not found. The upper mafic metavolcanic formation is about 8,000 feet thick in the Cape Chaillon fault block in Township 31, Range 20, but in the rest of the

map-area the maximum measured thickness is 4,450 feet on the southwest side of the Sundstrom Lake syncline near the north boundary of Township 31, Range 20; the top of the formation has been removed by erosion.

Contacts between mafic metavolcanic and other formations appear to be conformable and are sharp, interlayered, or intertongued. The interlayered or intertongued zone is seldom more than 100 feet thick; contacts are locally sheared.

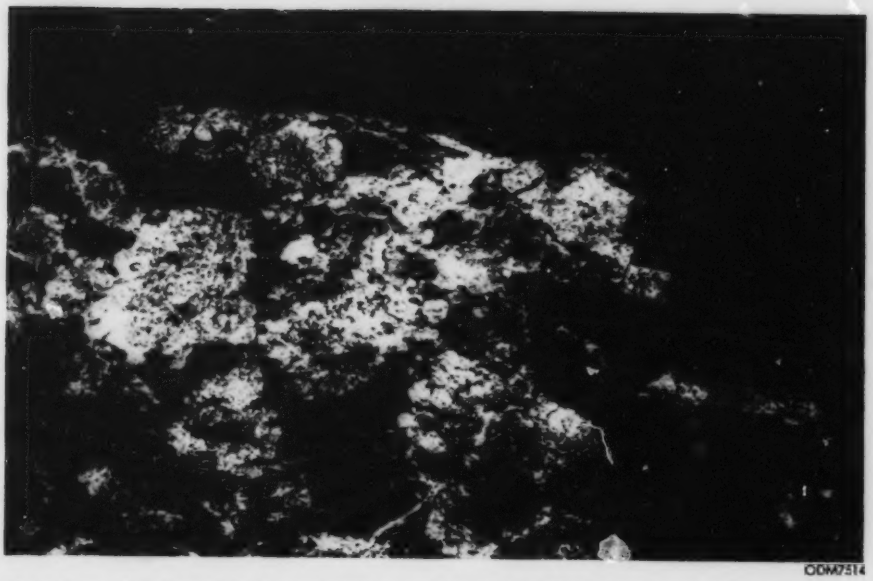
Mafic metavolcanics commonly contain more than thirty-five percent chlorite, amphibole, and pyroxene. They were derived dominantly from basaltic and andesitic flows and have been metamorphosed to the greenschist, almandine amphibolite, albite-epidote hornfels, hornblende hornfels, and pyroxene hornfels facies (facies defined according to Fyfe *et al.* 1958). With increasing metamorphic grade, the colour of the weathered surface varies systematically from pale-green to black and the colour of the fresh surface varies from dark-grey-green to black.

In the greenschist and albite-epidote hornfels facies there is a wide range in mineralogical composition, and the major mineral assemblages, in order of decreasing abundance, are (1) actinolite + albite (range An_5 to An_{10}; average An_8) $\pm$ epidote; (2) chlorite + albite (range An_3 to An_8; average An_5) + carbonate + epidote + quartz; (3) actinolite + epidote $\pm$ quartz $\pm$ carbonate; and (4) chlorite + epidote + carbonate + quartz. In the other facies mineralogical composition is less variable and the major mineral assemblages are blue-green hornblende + plagioclase (range An_{20} to An_{47}; average An_{33}) $\pm$ epidote $\pm$ quartz in the almandine amphibolite facies; blue-green hornblende + plagioclase (range An_{10} to An_{65}; average An_{35}) $\pm$ quartz, and plagioclase (range An_{23} to An_{68}; average An_{42}) + clinopyroxene $\pm$ dark-green hornblende in the hornblende hornfels facies; and plagioclase (range An_{34} to An_{80}; average An_{60}) + clinopyroxene + orthopyroxene $\pm$ brown hornblende in the pyroxene hornfels facies. Minor minerals in most of the facies are iron-titanium oxide, sphene, pyrite, pyrrhotite, apatite, and locally tourmaline.

Flow contacts are poorly exposed but flows appear to range in thickness from 20 feet to more than 150 feet. In flows greater than 50 feet thick (hereafter referred to as thick flows), medium-grained lava commonly forms more than fifty percent of the flow and, in poorly exposed outcrops, resembles metagabbro intrusions. Unless intrusive contacts were observed, medium-grained to coarse-grained mafic rocks were mapped as flows. In the greenschist facies, primary ophitic texture is commonly preserved in the medium-grained lava although, except for rare, primary, normally zoned oligoclase-andesine, hornblende, and clinopyroxene, the mineralogy is secondary. Thick flows rarely contain 10-foot to 15-foot thick coarse-grained layers which are in sharp but locally irregular contact with the medium-grained part of the flow. Thick flows form most of the upper mafic metavolcanic formation in the core of the Sundstrom Lake syncline and the upper part of the formation in the Cape Chaillon fault block; they are rare elsewhere in the map-area.

Flows less than fifty feet thick (hereafter referred to as thin flows) are dominantly fine-grained, and in the greenschist facies primary texture is locally preserved in thin flows in which chlorite and carbonate are rare. Primary, lath-shaped, normally zoned labradorite and andesine-labradorite are rarely preserved.

Equant, subhedral, labradorite and labradorite-bytownite phenocrysts as much as 6 centimetres in diameter but averaging 1 centimetre locally occur in thin mafic metavolcanic flows in the Belanger Lake anticline and in the Desbois Lake syncline (Photos 1, 2). Phenocrysts occur in both pillowed and non-pillowed



ODM7514

Photo 1 — Glomeroporphyritic metabasalt in hornblende hornfels facies, lower mafic metavolcanics; road-side rock cut on east side of Highway 17 near core of Belanger Lake anticline, Township 30, Range 19.

ODM7515

Photo 2 — Pillowed, porphyritic metabasalt in upper mafic metavolcanics; southwest corner of Township 30, Range 20. Note large phenocrysts in pillow selvage.

metabasalt and are irregularly distributed throughout the flow locally forming glomeroporphyritic aggregates and rare, thin, monomineralic layers; they locally occur in pillow selvages. Glomeroporphyritic flows are best exposed in road-side rock cuts in lower mafic metavolcanics in the Belanger Lake anticline in Township 30, Range 19. There, glomeroporphyritic aggregates as much as one foot in diameter (Photo 1) are concentrated in the lower part of 30-foot to 50-foot thick, metabasalt flows. Phenocrysts decrease in abundance upwards, and, in the central part of the flows, glomeroporphyritic aggregates give way to single phenocrysts; phenocrysts are rare in the pillowed upper part of the flows.

Rare flows originally contained equant pyroxene phenocrysts as much as two millimetres in diameter which are now pseudomorphed by actinolite.

A 250-foot thick layer of mafic metadacite occurs in the lower mafic metavolcanics in the core of the Surf Lake anticline near Highway 17. The metadacite contains 30 percent actinolite, 5 percent chlorite, and 25 percent discrete grains of quartz and albite (An_3) in a granophyric intergrowth of quartz and albite.

Pillows are common in upper mafic metavolcanics in the Desbois Lake syncline in Township 30, Range 20, and in the lower part of the formation in the Cape Chaillon fault block; they are present although not abundant elsewhere in the map-area. Pillows appear to occur in a higher proportion of thin flows than thick flows. Pillows are balloon-shaped, bun-shaped, and loaf-shaped, and are commonly 2 to 3 feet long and 1 to 2 feet high; pillows longer than 6 feet are rare. They commonly retain primary shape in the hornblende hornfels and pyroxene hornfels facies, but are locally distorted in the greenschist facies, especially in the lower mafic metavolcanics in the Surf Lake anticline. Distorted pillows are commonly 5 to 10 feet long but only 6 to 12 inches thick and have continuous, non-ruptured ½-inch to 1-inch wide selvages; the edges of the pillows are sharp rather than rounded. Most of the distortion probably occurred during orogeny and metamorphism, and distortion is a localized phenomenon because flows with non-distorted pillows are found only a few hundred feet above and below flows with distorted pillows.

Six-inch to five-foot thick breccia zones which contain lenticular to angular, felsic and rare mafic fragments as much as four inches long are locally found in the mafic flows. The fragments appear to be xenoliths which were either incorporated in the magma during its ascent or explosively ejected from a vent as blocks or lapilli. Other types of breccia are rare but locally contain pillow fragments and bombs.

Amygdules are rare and were found only in the upper mafic metavolcanics where they are ellipsoidal to lenticular with an average length of one millimetre. The following metamorphic, amygdule, mineral assemblages were found: (1) quartz, (2) carbonate, (3) carbonate-chlorite-pistacite, (4) carbonate-actinolite-pistacite, and (5) quartz-hornblende-chlorite-iron titanium oxide-pyrite-sphene.

Massive to poorly bedded mafic metatuff was rarely found in the upper mafic metavolcanics.

Gneissic mafic metavolcanics that probably formed by metamorphic differentiation are found in three places: in the higher grade metamorphic facies adjacent to the Rabbit Blanket Lake Trondhjemite in Township 30, Range 20; adjacent to, and in large roof pendants in the Gamitagama Lake Complex; and south of the Old Woman Lake fault in Range 19. Gneissic layers range in thickness from ¼ inch to 24 inches but average ¾ inch, are discontinuous, and resemble bedding. Adjacent layers have similar mineralogy but different proportions of minerals.

In the almandine amphibolite facies, dark-green hornblende-rich layers alternate with green plagioclase-rich layers. In the upper part of the hornblende hornfels facies, dark-green to black hornblende-rich layers alternate with dark-green clinopyroxene-rich layers. In the pyroxene hornfels facies, dark-green to black pyroxene-rich layers alternate with light-green plagioclase-rich layers, and dark-green to black clinopyroxene-bearing layers alternate with dark-green to black orthopyroxene-bearing layers. Retrograde metamorphism has locally formed prehnite-rich and pistacite-rich layers.

FELSIC METAVOLCANICS

A felsic metavolcanic formation which ranges in thickness from 0 to 2,000 feet and averages 1,600 feet occurs between the upper and lower mafic metavolcanic formations in most parts of the map-area (Fig. 2, 9 on Chart A, back pocket). On the north limb of the Surf Lake anticline in the eastern part of Township 30, Range 20, the formation forms two tongues which are separated by 500 to 1,750 feet of upper mafic metavolcanics. Felsic metavolcanics also form lenses and layers, which have a maximum thickness of 1,000 feet but are generally less than 200 feet thick in the other formations.

Felsic metavolcanics exhibit rapid lateral and vertical changes in lithology, but are dominantly pyroclastic deposits of sodic rhyolite and rhyodacite composition. Flows, which range in composition from sodic rhyolite to dacite, are locally found in the sequence. Felsic metavolcanics have been metamorphosed to the greenschist, almandine amphibolite, and hornblende hornfels facies, and, on fresh surfaces, they are white, yellow, pale-green, brown, grey, or rarely black. They commonly weather white, brown, or grey.

In the greenschist facies all rocks contain albite (range An_0 to An_9; average An_4), quartz, and commonly muscovite and epidote in addition to one of the following assemblages: chlorite + biotite, biotite, chlorite + carbonate, or chlorite + chloritoid. Chloritoid was found only in metatuff near Surf Lake in Township 31, Range 20. In the almandine amphibolite and hornblende hornfels facies, the common mineral assemblage is plagioclase (range An_{25} to An_{38}; average An_{30}) + quartz + biotite $\pm$ muscovite $\pm$ blue-green hornblende $\pm$ epidote. Hornblende and muscovite are mutually incompatible; garnet locally occurs in the almandine amphibolite facies. Minor minerals in most rocks include iron-titanium oxide, leucoxene, pyrite, apatite, and rare tourmaline. Paragonite was looked for in both felsic metavolcanics and metasediments but was not found.

Metamorphosed pyroclastic deposits, other than ash-flow tuff, form most of the felsic metavolcanic formation along the north limb of the Surf Lake anticline, and about half of the formation along the south limb. They are present at other localities but relative proportions could not be estimated. In order of decreasing abundance, these deposits comprise: metatuff, which has a grain size less than 2 millimetres; metalapillistone, which has fragments between 2 and 64 millimetres; and metamorphosed pyroclastic breccia, which contains fragments larger than 64 millimetres (Fisher 1961). These three types are complexly interlayered.

Metamorphosed lapillistone and pyroclastic breccia are most abundant along the north limb of the Surf Lake anticline in the western part of Township 30, Range 20 where they locally form fifty percent of the section. Fragments are commonly lenticular and less than four centimetres long, but northwest of Corner Lake near the top of the formation, angular blocks as much as 10 feet long

ODM7516

Photo 3 — Crenulated, laminated to very thin-bedded felsic metatuff on the north limb of the Surf Lake anticline; island in northeast arm of Mijinemungshing Lake, Township 29, Range 20. Outcrops of similar metatuff in the map-area are poorly exposed.

occur in a lapillistone matrix. Fragments are dominantly felsic but rare mafic fragments are present in most outcrops.

Bedding is well developed, but beds vary widely in thickness, are commonly discontinuous, and are locally wavy. Metatuff and fine metalapillistone are commonly laminated, very thin-bedded, or thin-bedded[1] (Photo 3); metamorphosed coarse lapillistone and pyroclastic breccia are commonly medium-bedded to very thick-bedded. Rare graded bedding was found.

Pyroclastic rocks are poorly sorted, and the framework varies from intact to disrupted. Medium-grained quartz and plagioclase crystals, which resemble phenocrysts, are common in all pyroclastic rocks.

Ash-flow tuff is a special type of pyroclastic deposit which was deposited from "a turbulent mixture of gas and pyroclastic materials of high temperature [ash flow], ejected explosively from a crater or fissure, that travels swiftly down the slopes of a volcano or along the ground surface" (Ross and Smith 1961, p.3). Many of the features used to identify ash-flow tuffs would be destroyed during greenschist facies metamorphism, but several features of the felsic metavolcanics on the south limb of the syncline in the Cape Chaillon fault block and on the north limb of the Sundstrom Lake syncline in Township 30, Range 20 suggest ash-flow origin.

In the Cape Chaillon fault block, a 900-foot thick, felsic metavolcanic unit is poorly layered to massive and contains medium-grained quartz and plagioclase phenocrysts and rare lenticular fragments as much as three inches long. In

[1]Bedding thickness is classified according to Dunbar and Rodgers (1957, p.97).

outcrop this unit does not have the characteristics of metatuff described previously. In thin section, however, abundance of tiny rock fragments, wide range in both size and abundance of phenocrysts, and heterogeneous texture suggest tuffaceous origin, and orientation of elongated plagioclase crystals suggests flowage. Thin section and field data can be best resolved by postulating deposition from an ash flow.

On the north limb of the Sundstrom Lake syncline, a 500-foot to 1,500-foot thick, conformable, quartz-plagioclase porphyry unit has been traced laterally for more than seven miles (Fig. 9 on Chart A). Metamorphism to the upper part of the greenschist facies and locally to the almandine amphibolite facies has completely destroyed primary matrix or groundmass textures, but the following features suggest ash-flow origin: (1) wide range in size and abundance of quartz and plagioclase phenocrysts, (2) orientation of plagioclase phenocrysts, (3) lack of small scale layering, (4) presence of quartz porphyry and rare non-porphyritic layers which range in thickness from five feet to several hundred feet, (5) presence of rare mafic fragments, and (6) presence of concordant, metamorphosed iron formation and mafic metavolcanic units within the porphyry. Many features of the porphyry are also compatible with pre-metamorphism intrusion of a porphyritic sill, but ash-flow deposition seems to be the more likely mode of origin.

Other possible ash-flow tuff units occur near the base of the formation northwest of Rathwell Lake in Township 31, Range 20, and in an anticline 2,500 feet west of Highway 17 in the south part of Township 30, Range 20.

Metamorphosed felsic flows form most of the formation on the south limb of the Surf Lake anticline in Township 30, Range 20 but decrease in abundance northwestward. They also form most of the formation west of Corner Lake in Township 30, Range 19.

Flows are commonly porphyritic with plagioclase and quartz phenocrysts, which, in contrast to phenocrysts in most pyroclastic rocks, have a small range in grain size in individual samples. Plagioclase phenocrysts are commonly oriented; quartz phenocrysts are generally recrystallized, but non-recrystallized phenocrysts are corroded. In the lower part of the greenschist facies, trachytic and granophyric groundmass textures are rarely preserved. Flow layering is poorly developed, and fragments are rare.

METASEDIMENTS

On the southwest side of the metavolcanic belt, a metasedimentary formation which is more than 9,500 feet thick appears to be equivalent in age to the entire metavolcanic sequence (Fig. 2 on Chart A; Fig. 3). Although the formation locally overlies the lower mafic metavolcanics and is commonly overlain by the upper mafic metavolcanics, neither the absolute top nor bottom is exposed. The maximum measured thickness in a continuous section is 4,050 feet on the east limb of the Gargantua Lake anticline southeast of Gargantua Lake in Townships 31 and 30, Range 19. In the Belanger Lake anticline in Township 30, Range 19, a metasedimentary tongue occurs in the stratigraphic interval, which, in other parts of the metavolcanic belt, is occupied by the felsic metavolcanic formation (Fig. 2, 9). On the north limb of the syncline in the southwest corner of Township 30 and the southeast corner of Township 31, Range 19, metasediments and upper

mafic metavolcanics are complexly intertongued, and a 5,000-foot thick section changes from dominantly mafic metavolcanics to dominantly metagreywacke in a lateral distance of about four miles.

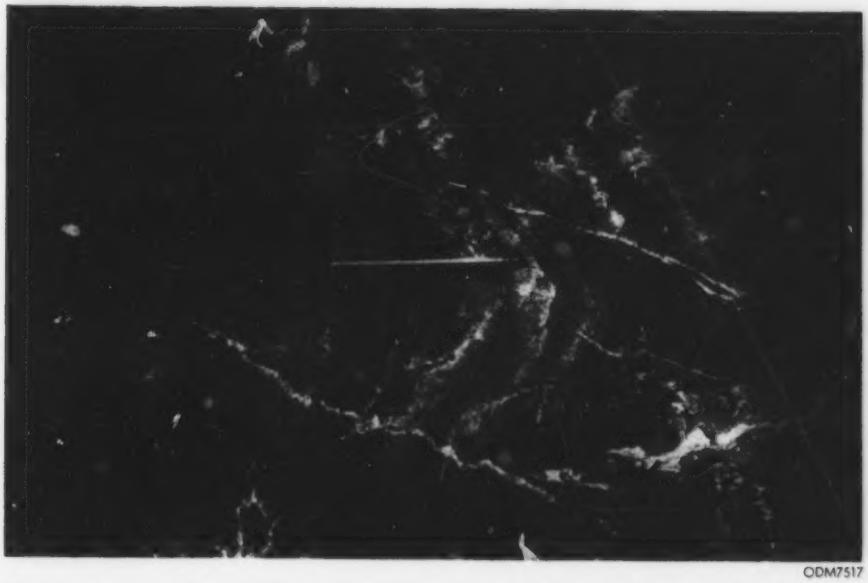
Metasedimentary lentils as much as 500 feet thick, some of which may be tongues of the metasedimentary formation, locally occur in the metavolcanic formations. The lentils are most abundant near the contact with the metasedimentary formation.

The metasediments are dominantly metagreywacke and metasiltstone with minor pebble and rare cobble metaconglomerate. Metaconglomerate is best developed near the contact with the upper mafic metavolcanics. Metasediments have been metamorphosed to the greenschist, almandine amphibolite, albite-epidote hornfels, and hornblende hornfels facies.

Metagreywacke and metasiltstone are commonly intimately interbedded but locally each rock type forms discrete members. Contacts between members are gradational and members could not be mapped. Metagreywacke is more abundant than metasiltstone, and, other than grain size, the major differences between the two rock types are: (1) higher biotite content, (2) more recrystallization, and (3) better foliation in metasiltstone than in metagreywacke. In the almandine amphibolite facies it is difficult to distinguish between these two rock types.

Metagreywacke and metasiltstone are commonly grey to dark-grey on fresh surfaces and very pale-grey to grey on weathered surfaces. The average composition is 40 to 50 percent plagioclase, 25 to 35 percent quartz, and 15 to 25 percent mafic minerals; sand-size rock fragments form as much as 60 percent of some samples. In the greenschist and albite-epidote hornfels facies, the major metamorphic mineral assemblages are albite + quartz + biotite $\pm$ muscovite $\pm$ epidote; albite + quartz + chlorite + biotite $\pm$ carbonate $\pm$ muscovite $\pm$ epidote; and albite + quartz + chlorite + carbonate $\pm$ muscovite $\pm$ epidote. In the almandine amphibolite and hornblende hornfels facies, all samples contain plagioclase (range An_{13} to An_{47}; average An_{25}), quartz, and biotite, and locally muscovite or blue-green hornblende. In the almandine amphibolite facies some samples also contain one of the following assemblages: garnet, staurolite, staurolite + garnet, andalusite + staurolite, and garnet + andalusite + staurolite + cordierite. Minor minerals in most samples are iron-titanium oxide, pyrite, pyrrhotite, apatite, and locally tourmaline and zircon. Rare garnet, cordierite, and clinopyroxene were found in the hornblende hornfels facies. In the almandine amphibolite facies hornblende and muscovite are mutually incompatible.

In the greenschist facies primary texture and mineralogy are preserved in much of the metagreywacke, and feldspathic metagreywacke is about three times more abundant than lithic metagreywacke. Sorting is poor and the framework is commonly disrupted. Primary plagioclase ranges in composition from oligoclase to labradorite. Although the source area for most of the plagioclase is unknown, the andesine-labradorite was probably derived from a mafic volcanic terrane and some of the oligoclase-andesine, especially those grains which have oscillatory and strong normal zoning, was probably derived from a felsic volcanic terrane. Detrital garnet and tourmaline were found in one sample. In order of decreasing abundance, sand-size rock fragments are equigranular felsic metavolcanics, porphyritic felsic metavolcanics, granophyre, mafic metavolcanics, and metachert. Mafic metavolcanic fragments are rare except near mafic metavolcanic formations.



ODM7517

Photo 4 — Contorted metagreywacke and metasiltstone with graded bedding in hornblende hornfels facies; road-side rock cut on east side of Highway 17 on north limb of Belanger Lake anticline, Township 30, Range 19. Top is toward pencil point.

Bedding is well preserved in the greenschist, albite-epidote hornfels, and hornblende hornfels facies, but is indistinct in most of the almandine amphibolite facies. Bedding ranges in thickness from thinly laminated (about 1 millimetre) to very thick-bedded (greater than 4 feet), but most of the formation is thin-bedded (1 inch to 3 inches). Within many outcrops there is a wide range in bedding thickness (Photo 4).

Grain gradation (Photo 4) is present in about twenty percent of the beds in Townships 31 and 30, Range 19, north of the Old Woman Lake fault, but is rare in other parts of the map-area. Two types of graded beds were recognized, both of which appear to form definite units within the formation. In the more common type, medium to coarse sand[1] grades upward to silt and rarely clay. The sand is poorly sorted, and silt-size quartz and plagioclase form as much as thirty percent of the rock. This type commonly forms a sequence of graded beds which range in thickness from laminated to very thick-bedded (Photo 4). Very coarse sand grains, fine foreign pebbles, and tabular, shale and siltstone pebbles are locally present in the basal part of thick beds. Foreign pebbles are most abundant in graded sequences west of Perederka Lake in Townships 31 and 30, Range 19 and in the metasedimentary tongue in the Belanger Lake anticline.

In the other type of graded bed, medium to coarse sand grades upward to fine or very fine sand in beds less than two inches thick which are commonly isolated in a sequence of poorly bedded, locally slaty metasiltstone. The meta-

[1]Grain size is classified according to Dunbar and Rodgers (1957, p.161).

ODM7518

Photo 5 — Polymictic cobble metaconglomerate composed of volcanic fragments; east of south end of Belanger Lake, Township 30, Range 19.

greywacke forms less than ten percent of the sequence but is better sorted than metagreywacke of the first type.

In some parts of the formation metagreywacke and metasiltstone are interbedded with sharp contacts and without grain gradation. Cross-bedding was found in one outcrop.

Polymictic pebble and cobble metaconglomerate forms units as much as 500 feet thick as follows: (1) at, or less than 500 feet below the contact with the upper mafic metavolcanics along at least fifty percent of the contact between Bushy Bay and Belanger Lake; (2) in the upper mafic metavolcanics near the contact with the metasedimentary formation north of Belanger Lake in Township 30, Range 19 and in the Cape Chaillon fault block; (3) in the metasedimentary tongue in the Belanger Lake anticline; (4) between Perederka Lake and the Fife Lake Granite; and (5) south of the Old Woman Lake fault in Range 19. Contacts with metagreywacke and metasiltstone are sharp to gradational.

Pebbles and cobbles are generally well rounded to subrounded in the greenschist and hornblende hornfels facies (Photo 5), but are lenticular in the almandine amphibolite facies. Cobble metaconglomerate is only locally developed and contains boulders as much as one foot in diameter. The coarsest grained metaconglomerate occurs at the contact with mafic metavolcanics.

Except for the unit south of the Old Woman Lake fault, all metaconglomerate in the map-area is similar and pebbles and cobbles are, in varying proportions, fine-grained mafic metavolcanics, medium-grained mafic metavolcanics, porphyritic mafic metavolcanics, equigranular felsic metavolcanics, porphyritic felsic metavolcanics, metachert, and quartz. Bedding is commonly absent but, where present, is thick to very thick. On the east side of the Fife Lake Granite in

Township 31, Range 19, well-bedded metaconglomerate in which each bed is graded from pebble metaconglomerate to lithic metagreywacke occurs 2,300 feet below the contact with the upper mafic metavolcanics. Metagreywacke between this metaconglomerate and the upper mafic metavolcanics contains rare pebbles and appears to have a higher proportion of lithic metagreywacke than other parts of the formation.

South of the Old Woman Lake fault in Township 30, Range 19, pebble metaconglomerate which has a maximum thickness of 500 feet occurs about 4,500 feet higher in the section (Fig. 2 on Chart A, back pocket) than, and is distinctly different from, other metaconglomerate. This unit occurs within intertongued metagreywacke and upper mafic metavolcanics, and, because it is continuous from the metasedimentary to the mafic metavolcanic facies, it is probably an isochronous unit. Pebbles are metagreywacke, mafic metavolcanics, equigranular felsic metavolcanics, porphyritic felsic metavolcanics, trondhjemite, and quartz. Trondhjemite pebbles retain their original rounded shape, but other fragments have been highly deformed. The trondhjemite is equigranular and fine-grained to medium-grained.

Poorly bedded, metamorphosed sandstone, conglomerate, and breccia which contain one or more of the magnesian amphiboles anthophyllite, cummingtonite, and pargasite form about two percent of the metasedimentary tongue on the north limb of the Belanger Lake anticline. These rocks are well exposed in road-side rock cuts and locally contain zoned and unzoned, spherical to ellipsoidal nodules which range in diameter from 1 inch to 3 inches. The average composition of these rocks is 50 percent plagioclase (range An_{29} to An_{50}; average An_{40}), 15 percent quartz, 8 percent biotite, 25 percent magnesian amphiboles, and 2 percent other minerals including iron-titanium oxide, pyrite, and apatite; rare garnet and cordierite are present. These rocks are interbedded with normal metagreywacke and metaconglomerate and appear to represent pyroclastic and epiclastic deposits of unusual composition; metasomatism was probably minor. Anthophyllite was also found in metaconglomerate in Township 31, Range 20, about 500 feet southeast of the Chaillon Lake Quartz Monzonite.

Metasediments which are metamorphosed to the upper part of the almandine amphibolite facies form about fifty percent of the Ryan Migmatite. These metasediments were probably derived from metagreywacke, have an average grain size of 0.5 to 1 millimetre, and contain 35 to 60 percent plagioclase (range An_{18} to An_{34}; average An_{26}), 20 to 40 percent quartz, 8 to 36 percent biotite, minor amounts of garnet, muscovite, pistacite, and hornblende, and trace amounts of pyrite, pyrrhotite, iron-titanium oxide, apatite, zircon, allanite, and sphene. Relic bedding which ranges in thickness from ½ inch to 6 inches is preserved in most of these metasediments (Photo 7). Metasedimentary inclusions in granitic rocks elsewhere in the map-area are mineralogically similar to the metasedimentary component of the Ryan Migmatite.

METAMORPHOSED IRON FORMATION

Iron-rich units occur in the lower and upper mafic metavolcanic, felsic metavolcanic, and metasedimentary formations but appear to be restricted to a 2,000-foot thick, stratigraphic interval, the middle of which is about 500 feet below the contact between the lower mafic metavolcanic and felsic metavolcanic formations. Some of the iron-rich units contain less than fifteen percent iron,

which according to Gross (1965, p.83) is the lower limit for iron formation, and are thus ferruginous metasediments or ferruginous metachert rather than metamorphosed iron formation.

In the mafic metavolcanics most of the iron-rich units occur on the north limb of the Surf Lake anticline in Township 30, Range 20 and were briefly described by Coleman (1906). The thickest lentil is in lower mafic metavolcanics immediately east of Highway 17 and is at least 3,000 feet long with a maximum thickness of 350 feet; it is truncated on the west by the Red Rock Lake fault. Metamorphosed iron formation is reported to occur (A. M. Goodwin, oral communication, 1963) on the south limb of the Surf Lake anticline about 1½ miles east of Highway 17 near the Mijinemungshing Lake access road, but was not found by the author.

All iron-rich units in the Surf Lake anticline were metamorphosed to the lower greenschist facies and are petrographically similar. Metachert layers commonly alternate with magnetite-rich layers, but locally siderite, dolomite, and iron silicate mineral layers are present. Layers are discontinuous and range in thickness from a fraction of a millimetre to about 60 centimetres but average 5 to 10 millimetres; magnetite, siderite, dolomite, and rare iron silicate mineral layers are commonly less than one centimetre thick. No primary texture was found; grain size is 0.01 to 0.02 millimetre.

Metachert contains trace to thirty percent anhedral to euhedral magnetite and, depending on the magnetite content, varies in colour from white to black; most metachert contains less than five percent magnetite. Thick metachert layers are laminated to thinly laminated with laminae marked by slight colour variations.

Magnetite-rich layers contain some quartz but are in sharp contact with black, magnetite-bearing metachert.

Green siderite layers are most abundant in magnetite-poor sections of the iron formation and are commonly rusty-weathering. Siderite layers generally contain quartz-filled fractures that are approximately perpendicular to the layering and do not extend into adjacent metachert layers. The fractures probably formed by desiccation of the siderite. Dolomite forms white, concordant layers and discordant veins.

Magnetite-rich layers are most abundant in the upper half and lower quarter of the thickest lentil. A grab sample of black chert with magnetite-rich layers collected by the author from the upper part of the lentil contained 11.46 percent iron.

West of Corner Lake, a 50-foot thick unit of layered, almandine amphibolite facies, ferruginous metasediments occur in lower mafic metavolcanics. The unit contains about ten percent magnetite and the average grain size is 0.1 millimetre.

The only thick metamorphosed iron formation unit in felsic metavolcanics is a 50 to 60-foot thick unit in metamorphosed ash-flow tuff in Township 30, range 20, west of Red Rock Lake. This unit was briefly described by Coleman (1906, p.179) and is composed of alternating, commonly discontinuous, locally contorted, metachert and magnetite-rich layers which range in thickness from 1 millimetre to 5 centimetres. Dark-green grunerite layers are locally present. This unit was metamorphosed to the uppermost part of the greenschist facies and the average grain size is 0.2 millimetre. Magnetite-rich layers are most abundant at the top of the unit, and a grab sample taken by the author from the top contained 34.9 percent iron.

In the metasedimentary formation, ferruginous metasediments and metamorphosed iron formation were found on the east limb of the Gargantua Lake anticline in Townships 31 and 30, Range 19 and north of Chaillon Lake in Township 31, Range 20. A magnetite-rich grab sample collected by the author north of Chaillon Lake contained only 17.78 percent iron; most of the iron-rich metasediments probably contain less than 15 percent iron.

One-half-inch to fifty-foot thick ferruginous metasedimentary units are interlayered with metagreywacke and metasiltstone units to form sequences as much as 400 feet thick. Contacts between units are sharp, and ferruginous units commonly form less than twenty-five percent of the sequence. Iron-rich metasedimentary members shown on Maps 2138 and 2139 include the interlayered metagreywacke and metasiltstone units.

The ferruginous metasediments are commonly thinly laminated and are rarely contorted; laminae range in thickness from 1 to 20 millimetres. Alternating laminae are quartz-plagioclase and quartz-plagioclase-mafic minerals-magnetite. In the greenschist facies on the east limb of the Gargantua Lake anticline, the average grain size is 0.03 millimetre, and the mafic minerals are biotite and chlorite. In the almandine amphibolite facies north of Chaillon Lake, the average grain size is 0.1 millimetre and the mafic minerals are biotite, chlorite, pistacite, and garnet. Magnetite forms 10 to 20 percent of these metasediments.

The lack of primary textures and association with metavolcanics and metagreywacke indicate that the metamorphosed iron formation is the Algoma type of Gross (1965).

METAVOLCANIC-METASEDIMENTARY STRATIGRAPHY

The metavolcanic assemblage appears to belong to the basalt-andesite-rhyolite association (Turner and Verhoogen 1960). Metavolcanics of intermediate composition and quartz-poor and potassia-rich felsic metavolcanics are rare.

Pillow structure indicates that at least some of the mafic volcanism was subaqueous. In the upper mafic metavolcanics, thin, commonly pillowed metabasalt and meta-andesite flows are best developed near subaqueously deposited metasediments and were probably extruded subaqueously. Thick, less commonly pillowed meta-andesite(?) flows have their maximum development in areas far removed from metasediments and may have been, at least in part, extruded subaerially. The thin flows may represent the flank of a north-northwest-trending volcanic ridge, possibly part of an island arc, and the thick flows may represent the higher, central part of the ridge (Fig. 3). In the upper mafic metavolcanic formation, felsic metavolcanic lenses, which are dominantly pyroclastic in origin, form about ten percent of sequences of thick flows but are rare in sequences of thin flows. If the thin flows represent the subaqueous flank of a volcanic ridge, felsic pyroclastic detritus originally deposited in this part of the section may have been transported into the adjacent sedimentary basin by slumping and turbidity currents. (Transportation of pyroclastic debris by slumping and turbidity currents has been demonstrated in the Cenozoic of Washington by Fiske [1963].)

The complex interfingering of mafic and felsic metavolcanics, and the occurrence of felsic metavolcanic lenses in mafic metavolcanic formations indicate that both types of volcanism occurred throughout the entire volcanic episode and were locally coeval, but sharp contacts between felsic and mafic units indicate relatively abrupt changes in type of volcanism.

Townships 31 and 30

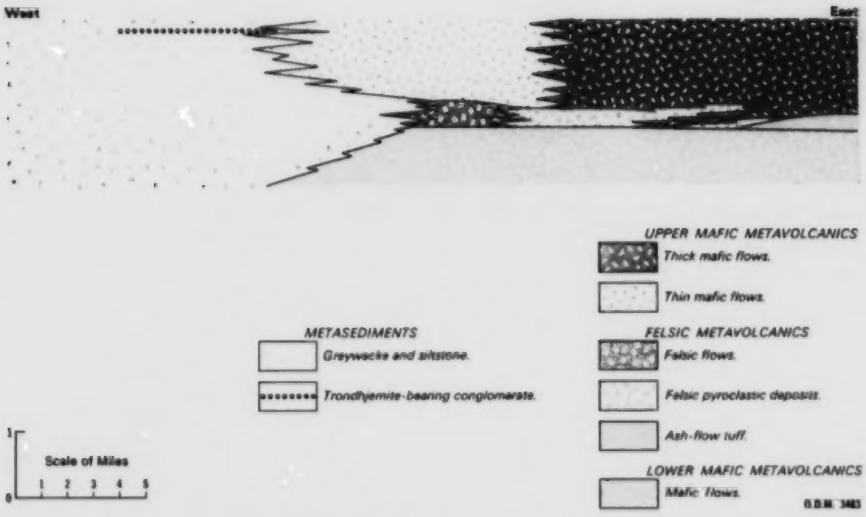


Figure 3 — Diagrammatic cross-section showing inferred, pre-folding relationships within the metavolcanic-metasedimentary sequence.

Felsic metavolcanics are sodic rhyolite and rhyodacite in composition and felsic volcanism was dominantly explosive. Within the felsic metavolcanic formation, which has a smaller areal extent than either the overlying or underlying mafic metavolcanic formation, thick sequences of flows and pyroclastic breccia which probably mark the site of vents are found in the southwest part of Township 30, Range 20 where flows occur on the south limb of the Surf Lake anticline and pyroclastic breccia on the north limb, and in the southeast corner of Township 30, Range 19. Ash-flow tuff in Township 30, Range 20 is separated from the possible vent area in the southwestern part of the township by a thick sequence of metatuff, and the source of the ash-flow tuff may have been north of the present outcrop area. The recognized vent areas occur near the edge of the metavolcanic belt, and the vents supplied detritus for the tuff deposits near the centre of the volcanic ridge, and to the flanking sedimentary basin (Fig. 3).

Metasedimentary and metavolcanic facies are locally complexly intertongued and sedimentation appears to have been synchronous with volcanism (Fig. 2). Metagreywacke and metasiltstone were deposited in a basin on the west side of the volcanic ridge. Most metaconglomerate is spatially associated with, and was derived from, the volcanic terrane and must reflect tectonic uplift and subaerial erosion of the volcanic ridge.

At least some of the metagreywacke and metasiltstone was derived from a felsic and locally mafic volcanic terrane, but the quartz content of the metasediments is too high to have been derived solely from a volcanic terrane comparable in composition to the volcanic belt. Sand-size quartz forms about 5 percent of preserved felsic metavolcanics and about 15 percent of the metasediments. Thus, if sand-size quartz was derived solely from eroded, pyroclastic,

felsic rocks, the volume of felsic volcanic rocks erupted and dispersed to the sedimentary basin must have been at least three times greater than the total volume of the metasediments, and larger than the entire preserved volcanic sequence. No evidence of such extensive felsic volcanism was found.

Alternative sources are a plutonic-metamorphic complex or an older sedimentary formation. In the upper part of the formation a trondhjemite source provided pebbles for the metaconglomerate in the southwest corner of Township 30, Range 19. Rare detrital garnet and tourmaline found in some of the metagreywacke may have been derived from a metamorphosed terrane. In the Michipicoten area, Bass (1961) reported trondhjemite, tonalite, and soda granite fragments in the Dore metaconglomerate that Goodwin (1962; and oral communication 1964) has shown to thin and to become finer-grained eastward. Thus a quartz-rich, potassia-poor plutonic-metamorphic terrane may have existed west of the map-area and provided clastic material to both the map-area and the Michipicoten area. The trondhjemite-bearing metaconglomerate in the map-area is isochronous, crosses facies boundaries, and probably reflects tectonic uplift in the plutonic-metamorphic source area.

During lulls in the volcanism and sedimentation, iron formation was chemically precipitated in both the volcanic and sedimentary environments. Maximum development in both environments occurs within a 2,000-foot thick interval in the lower part of the sequence.

The maximum thickness of the metavolcanic-metasedimentary sequence is 11,000 feet. Much of the section is probably missing.

CORRELATION WITH THE MICHIPICOTEN REGION

The Michipicoten region and the map-area appear to be part of the same metavolcanic-metasedimentary sequence, but they are separated by 13 miles of unsubdivided metavolcanics (Matheson 1933; A.C.R. 1964a) and by the Brulé Bay batholith which has a minimum width of two miles. In the Michipicoten region, Goodwin (1962) recognized three metavolcanic and two metasedimentary formations aggregating more than 15,000 feet in thickness. Tentatively the metasedimentary formation in the map-area has been correlated with the Dore sedimentary rocks, but other formations cannot be correlated.

PRE-KEWEENAWAN INTRUSIONS

Metagabbro and Metadiorite

In many poorly exposed outcrops in the mafic metavolcanic sequence, it is difficult or impossible to determine whether a medium-grained to coarse-grained, metamorphosed mafic rock is a metagabbro or metadiorite intrusion or the central part of a thick flow; unless intrusive contacts were observed controversial outcrops were assumed to be mafic flows. The only positively identified, metamorphosed, mafic intrusions in mafic metavolcanics are rare, small, irregularly-shaped, fine-grained to medium-grained masses which intrude pillowed flows. These intrusions appear to be restricted to the flow in which they occur and are probably genetically related to that flow.

Townships 31 and 30

Slightly discordant, fine-grained to medium-grained, mafic dikes with chilled margins are locally present in the metasediments and rarely in the felsic metavolcanics. The dikes are as much as 100 feet wide but are commonly less than 10 feet wide. In the almandine amphibolite facies, narrow dikes are locally boudinaged. The largest dike intrudes metasediments and felsic metavolcanics in the Cape Chaillon fault block; primary ophitic texture is locally preserved and the maximum grain size is five millimetres. Similar dikes probably occur in the mafic metavolcanic formations but were not recognized.

All metagabbro and metadiorite intrusions have been metamorphosed to the same grade as enclosing formations and are petrographically similar to mafic metavolcanics of comparable grain size and metamorphic grade. They were probably intruded during volcanism.

Metamorphosed Ultramafic Rocks

Metamorphosed ultramafic rocks, probably metapyroxenite, were found at two localities: (1) a 25-foot wide, medium-grained dike in upper mafic metavolcanics near Cape Chaillon in Township 31, Range 20 which is composed of 35 percent, subhedral, pale blue-green actinolite, 25 percent, colourless tremolite which mantles the actinolite, 35 percent biotite, 5 percent chlorite, and trace amounts of sphene, apatite, and iron-titanium oxide; and (2) an isolated medium-grained outcrop in metasediments east of Highway 17 near the south boundary of Range 19, which is composed of 67 percent colourless tremolite, 15 percent biotite, 15 percent chlorite, 3 percent quartz, and trace amounts of apatite, iron-titanium oxide, and pyrite.

At both localities the rock is soft, pale-grey on weathered surfaces, and green on fresh surfaces. Outcrop surfaces are commonly pitted. The origin and age of these ultramafic rocks is not known.

Sodic Granitic Sills and Dikes

Several fine-grained, porphyritic, sodic metarhyolite dikes, which were metamorphosed to the same grade as enclosing upper mafic metavolcanics and are probably genetically related to volcanism, occur near the beaver pond in the west-central part of Township 30, Range 20. The dikes range in width from 2 to 20 feet, are perpendicular to the mafic flows, and have a flow layering parallel to dike contacts with a metamorphic foliation perpendicular to this layering.

Metamorphosed, porphyritic, trondhjemite dikes which range in width from 2 to 10 feet and have sharp, concordant to discordant contacts are locally found in the metavolcanic-metasedimentary sequence but are most abundant near the common corner of the four townships. The dikes are pale-grey to grey on both fresh and weathered surfaces and contain medium-grained to coarse-grained oligoclase-andesine and locally recrystallized quartz phenocrysts in a very fine-grained recrystallized groundmass composed of quartz, oligoclase, biotite, chlorite, actinolite, epidote, muscovite, and carbonate. The grade of metamorphism appears to be less than that of enclosing formations, and the dikes probably represent the first phase of plutonic activity.

A small, trondhjemite-granodiorite intrusion with variable microcline content occurs on the west side of Highway 17 about 1,500 feet south of the Range 20–Range 19 boundary. It was intruded and metamorphosed to the hornblende hornfels facies by the Gamitagama Lake Complex and has been

recrystallized to a granular mozaic of 0.2-millimetre oligoclase (An_{24}), quartz, and microcline. Muscovite, biotite, andalusite, garnet, tourmaline, and apatite form about ten percent of the intrusion.

Medium-grained, equigranular trondhjemite and albite granite sills, which range in width from 5 to 50 feet, are locally found in the metavolcanic-metasedimentary sequence but are generally less than two miles from large batholiths containing trondhjemite phases. The sills lack chilled margins and are slightly recrystallized, although the degree of recrystallization is similar to that in trondhjemite pebbles in almandine amphibolite facies metaconglomerate. These sills are probably synmetamorphic and related to batholithic intrusions but may be premetamorphic and related to volcanism.

Rabbit Blanket Lake Trondhjemite

The Rabbit Blanket Lake Trondhjemite underlies the northeast part of Township 30, Range 20 and forms the southern margin of a large composite batholith which separates the metavolcanic-metasedimentary belt described herein from a similar belt in the Michipicoten region (A.C.R. 1964a). The batholith was first described by Coleman (1906, p.191) near Brulé Bay in Township 31, Range 21 and is here named the Brulé Bay batholith. Other phases of the batholith in the map-area are the Kasubeck Creek Granodiorite, which intruded the trondhjemite near Highway 17, and red granite in a fault block on the shore of Lake Superior near the Range 21–Range 20 boundary.

The Rabbit Blanket Lake Trondhjemite comprises medium-grained, equigranular to porphyritic, foliated to gneissic, hornblende-biotite trondhjemite and rare tonalite and diorite which weather pale-grey to grey and are grey to dark-grey on fresh surfaces. Modal analyses are presented in Table 1.

Table 1 | *Modes of Rabbit Blanket Lake Trondhjemite*

	TRONDHJEMITE					TONALITE
	62-A-150-1	62-A-151-1	62-A-159-3	62-A-485-1	62-J-70-2	62-A-454-1
Plagioclase	50.1	60.6	53.0	47.2	55.1	47.3
Potassic feldspar	2.0	2.5	2.0	....	....	....
Quartz	34.2	20.7	33.3	32.7	28.6	31.7
Hornblende	....	2.5	....	5.4	6.3	9.4
Biotite	11.8	2.0	8.8	9.0	0.3	0.6
Chlorite	trace	4.6	trace	0.6	5.0	6.3
Pistacite	1.8	6.2	2.8	4.9	4.1	2.5
Prehnite	....	0.2	....	....	trace	1.2
Others[1]	0.1	0.7	0.1	0.4	0.6	1.1
Plagioclase[2] composition	27→23	38→26	28→23	38→26	24→21	47→26

NOTES

[1]apatite, zircon, sphene, allanite, Fe-Ti oxide, carbonate, chalcopyrite.

[2]Plagioclase composition is given in percent anorthite component. When plagioclase is zoned (→), both core and rim compositions are shown.

Contaminated, porphyritic trondhjemite which grades northward into equigranular trondhjemite forms a border zone as much as 2,000 feet wide adjacent to gneissic lower mafic metavolcanics. The contact with the metavolcanics is sharp and concordant, and sills and dikes are rare in the metavolcanics. Mafic

metavolcanic inclusions are rare in the contact zone, but the mafic mineral content and the ratio of hornblende to biotite are both higher than elsewhere in the mapped part of the intrusion. Plagioclase phenocrysts are augen-like and as much as one centimetre long.

Inclusions and segregations of diorite, tonalite, and fine-grained trondhjemite are locally found in the equigranular medium-grained trondhjemite.

An almandine amphibolite facies, contact metamorphic aureole as much as 2,000 feet wide is present adjacent to the trondhjemite. The trondhjemite appears to be an early phase of the batholith and was probably emplaced in the lower part of the mesozone of Buddington (1959).

Mijinemungshing Lake Trondhjemite

A small stock centred on Mijinemungshing Lake in Township 29, Range 20 and intruded into the Surf Lake anticline (Fig. 9) is composed of grey to white, medium-grained, gneissic to foliated, augen trondhjemite and granodiorite. Two outcrops at the east edge of Township 30, Range 20 are composed of 30 percent quartz, 40 to 55 percent oligoclase-andesine, 5 to 10 percent perthitic microcline, 10 to 15 percent biotite, 5 percent pistacite, and trace amounts of muscovite, chlorite, apatite, zircon, carbonate, iron-titanium oxide, and leucoxene. The rocks are partly recrystallized and are locally granulated. Gneissosity is produced by oriented quartz lenses and by narrow lenses and layers of mafic minerals.

The recrystallization and cataclasis were probably caused by intrusion of the nearby Gamitagama Lake Complex. The stock may be coeval with the Rabbit Blanket Lake Trondhjemite.

Older Porphyritic Potassic Granitic Sills and Dikes

There are two ages of porphyritic, potassic, granitic sills and dikes: (1) dikes which are older than the Baldhead River Quartz Monzonite are common throughout the metavolcanic-metasedimentary sequence and appear to be at least three times more abundant than the porphyritic sodic dikes previously described; and (2) dikes which are found near, and are related to, the Baldhead River Quartz Monzonite (p.34).

The older intrusions are concordant to discordant with sharp contacts and range in size from dikes less than 2 feet wide to sill-like masses as much as 2,500 feet long and 500 feet wide. In order of decreasing abundance, these intrusions are composed of potassic granite, sodic granite, and quartz monzonite. They are pale-brown or white on fresh surfaces, weather white, pale-brown, or pale-pink, and contain medium-grained albite-oligoclase, perthitic microcline, quartz, and locally biotite phenocrysts in a very fine-grained groundmass composed of quartz, plagioclase, microcline, biotite, and muscovite.

Recrystallization is minor and is generally restricted to quartz phenocrysts, and the dikes appear to have been intruded after the culmination of the main period of metamorphism but before the intrusion of the Gamitagama Lake Complex.

Southern Batholith

The southwestern part of the map-area and the southeast corner of Township 30, Range 19 are underlain by part of a large granitic batholith which extends at least 30 miles south of the map-area (A.C.R. 1964a; O.D.M. Map P.302). In Township 31, Ranges 20 and 19, the batholith has been divided into three

formations which, from oldest to youngest, are the Gargantua Harbour Porphyritic Granodiorite, the Ryan Migmatite, and granitic rocks on the east side of the porphyritic granodiorite. The latter two formations are probably coeval.

The batholith is generally concordant although contacts are poorly exposed and are offset by several faults. Country rocks have been metamorphosed to the almandine amphibolite facies. The eastern margin of the batholith is intrusive into the metasedimentary-metavolcanic sequence and appears to be in the mesozone of Buddington (1959). The Ryan Migmatite is in the lower part of the mesozone or transition between the mesozone and catazone and may have formed by a combination of intrusion, metasomatism, and partial melting of metasediments.

Gargantua Harbour Porphyritic Granodiorite

Porphyritic granodiorite which is characterized by subhedral, commonly pink microcline phenocrysts as much as six centimetres long underlies about 10 square miles and is bordered on the west by the Ryan Migmatite, and on the east by equigranular granitic rocks. The formation is dominantly granodiorite but ranges in composition from trondhjemite to quartz monzonite. The rocks are medium-grained and massive to foliated. Their range in composition is: 35 to 55 percent calcic oligoclase; 20 to 30 percent quartz; trace to 40 percent perthitic microcline; 5 to 20 percent biotite and chlorite; trace to 5 percent muscovite; and trace to minor amounts of pistacite, apatite, zircon, sphene, allanite, carbonate, prehnite, iron-titanium oxide, and pyrite. Phenocrysts average 5 to 10 percent of the granodiorite but range from locally absent to 30 percent. Small areas of equigranular granodiorite within the intrusion apparently reflect absence of phenocrysts.

Table 2 | *Modes from the Gargantua Harbour Porphyritic Granodiorite*

	GRANODIORITE INCLUSIONS		FINE-GRAINED TO MEDIUM-GRAINED LEUCOCRATIC DIKES				DIKE FROM THE RYAN MIGMATITE
	61-A-301-2	61-P-183-1	61-A-466-4	61-A-480-3	61-A-520-1	61-A-523-1	61-A-347-2
Plagioclase	47.5	47.0	54.3	42.0	25.4	32.4	42.2
Potassic feldspar	13.9	6.1	17.1	24.9	46.1	31.6	19.6
Quartz	19.8	25.1	24.4	25.2	27.4	34.3	28.2
Biotite	14.0	16.3	1.8	2.1	0.5	0.2	8.4
Chlorite	trace	...	0.2	0.6	trace	0.8	0.2
Muscovite	2.1	0.3	1.8	3.6	0.6	0.5	1.4
Pistacite	1.0	3.8	...	1.1	...	0.2	...
Sphene	1.1	0.9	...	0.3	...	trace	...
Garnet	...	...	...	...	trace	...	...
Allanite	0.1	0.2	...	trace	...	...	...
Others[1]	0.5	0.3	0.4	0.2	...	trace	trace
Plagioclase composition[2]	26	27→23	19→14	5	4	5	20
Potassic feldspar / Total feldspar	.23	.12	.24	.37	.64	.49	.32

NOTES

[1]apatite, zircon, carbonate, pyrite, hematite, Fe-Ti oxide.
[2]Plagioclase composition is given in percent anorthite component. When plagioclase is zoned (→), both core and rim compositions are shown.

Rare angular inclusions of fine-grained to medium-grained, foliated to massive, equigranular granodiorite (Table 2) are present in the southern part of the body. Metasedimentary inclusions are found throughout the body. They range in size from less than one inch to mappable units several hundred feet wide, and vary in shape from angular to concordant layers.

At least four different types of granitic dikes intrude the granodiorite. In order of decreasing age these are: (1) pink, granitic pegmatite; (2) pink to white, medium-grained to coarse-grained leucogranite, which is associated with, and appears to grade into pegmatite; (3) pink, fine-grained to medium-grained leucogranite (Table 2); (4) fine-grained to medium-grained, biotite granodiorite and quartz monzonite (Table 2). The pegmatite and medium-grained to coarse-grained leucogranite are the dominant dike rocks in the southern part of the body, and fine-grained to medium-grained leucogranite is the dominant type in the northern part. The biotite granodiorite and quartz monzonite are most abundant at the margins of the body and appear to be related to the granitic phase of the Ryan Migmatite and also to equigranular granitic rocks on the east side of the body.

Ryan Migmatite

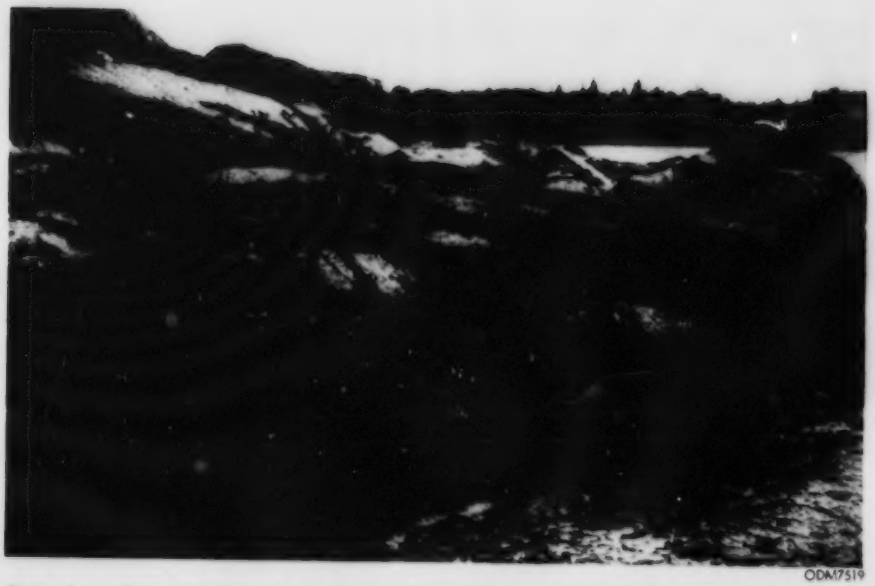
A migmatite composed of approximately equal amounts of metasedimentary and granitic rocks underlies about 15 square miles on the west side of the Gargantua Harbour Porphyritic Granodiorite. The migmatite is about 12,000 feet thick, 5,000 feet of which are metasediments which may be part of the metasedimentary formation. The low dip is probably the result of southwestward tilting during the Keweenawan (p.47).

The metasedimentary and granitic components have a non-random distribution, and metasedimentary areas which have an average content of 25 percent granitic rocks (Photo 6) can be distinguished from granitic areas which contain about 30 percent metasediments. Areas containing approximately equal amounts of metasedimentary and granitic rocks are rare except for narrow zones separating granitic and metasedimentary areas.

The granitic rocks commonly form concordant sills which are parallel to relic bedding in the metasediments (Photo 6). The sills pinch and swell, lens out, and bifurcate (Photo 6) and range in thickness from less than ¼ inch to several hundred feet; the spacing between sills ranges from ¼ inch to several tens of feet. Because of the concordant nature of the granitic component, metasedimentary areas can be traced for long distances along strike.

The granitic rocks are massive to locally foliated, equigranular to locally porphyritic, medium-grained, biotite trondhjemite and granodiorite. Minor tonalite, quartz monzonite, albite granite, sodic granite, and rare albite syenite and syenodiorite are present. All narrow sills are trondhjemite, and the distribution of samples suggests that the wider sills grade from trondhjemite at the margin to granodiorite and locally quartz monzonite in the centre. Contacts between granitic sills and metasediments are sharp with no chilling of the granitic rock or change in composition of the metasediments.

Pegmatite composed of albite, microcline, quartz, biotite, and muscovite forms dikes, sills, and irregular bodies as much as 12 feet wide which intrude both components of the migmatite (Photo 7). Contacts are generally sharp but are locally gradational, and the maximum grain size is one foot. Pegmatite generally forms less than 5 percent of the outcrop area but locally forms as much as 60 percent.



ODM7519

Photo 6 — Ryan Migmatite; Lake Superior, Ryan Mineral Location. Note concordant nature and pinch and swell of granitic component.

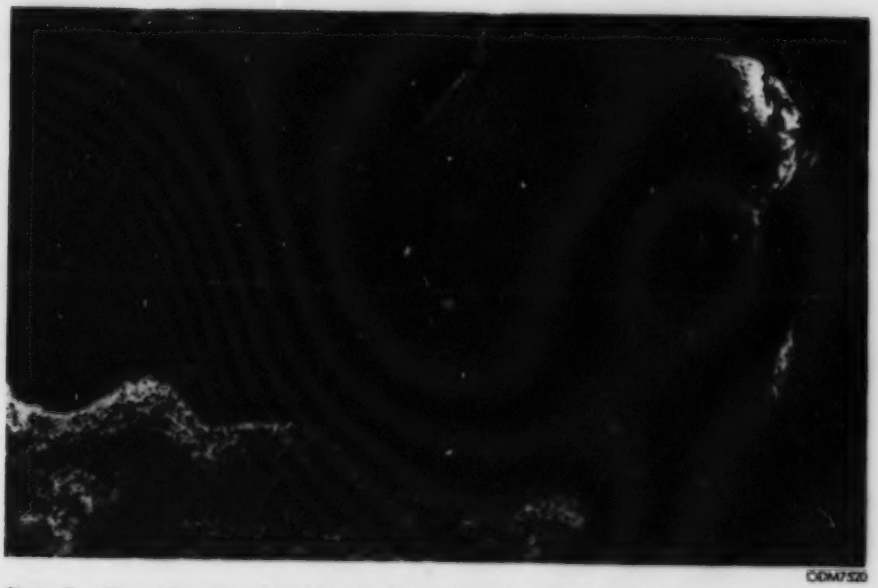


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Photo 7 — Ryan Migmatite; Lake Superior, Ryan Mineral Location. Note discordant pegmatite, relic bedding, and minor folds within some metasedimentary layers.

Townships 31 and 30

Other Granitic Rocks

On the east side of the Gargantua Harbour Porphyritic Granodiorite (in Township 31, Ranges 20 and 19), a zone as much as 1½ miles wide is formed by granitic rocks which intruded the porphyritic granodiorite, metasediments, and upper mafic metavolcanics. The Fife Lake Granite occurs in this zone but appears to be slightly younger (p.35). A migmatite zone as much as 1,000 feet wide occurs in metasediments adjacent to the granitic rocks and a 200-foot wide migmatite zone occurs in mafic metavolcanics. Metasedimentary inclusions, both angular blocks and long tabular slabs, are common and are more abundant than in adjacent parts of the porphyritic granodiorite. Angular gneissic mafic metavolcanic inclusions are locally present.

The granitic rocks are massive to foliated, fine-grained to medium-grained, equigranular to rarely porphyritic, biotite granodiorite, trondhjemite, and minor quartz monzonite, granite, and syenite. Narrow pegmatite and medium-grained leucogranite dikes are locally present.

The edge of the batholith is also exposed in the southeast corner of Township 30, Range 19, where fine-grained to medium-grained, locally porphyritic, foliated, biotite trondhjemite, granodiorite, quartz monzonite, and granite intrude lower mafic metavolcanics. A 500-foot wide migmatite zone is present in the mafic metavolcanics, and, immediately adjacent to the migmatite, the granitic rocks are highly sheared and recrystallized. The degree of recrystallization decreases eastward.

Gamitagama Lake Complex

The Gamitagama Lake Complex is a calc-alkaline stock, elliptical in plan, which underlies 27.5 square miles in Townships 30 and 29, Ranges 20 and 19, and ranges in composition from olivine norite and gabbro to syenite (Fig. 4). Two satellitic intrusions which have an aggregate area of one square mile occur on the west side of the stock.

The stock is rudely zoned outwards from an eccentric olivine gabbro and norite core through gabbro and norite, pyroxene diorite, biotite-hornblende diorite, tonalite, and trondhjemite to granodiorite, and quartz monzonite. Syenite and monzonite intrude all other rock types. Only five units could be mapped in the field and from oldest to youngest these are: pyroxene gabbro and diorite; andesine anorthosite; biotite-hornblende diorite, tonalite, syenodiorite, and trondhjemite; leucocratic granodiorite and quartz monzonite; and syenite and monzonite. Except for the syenite-monzonite unit, contacts between rock types are generally gradational and are difficult to map. Chemical analyses and modes are given in Table 3.

The complex was forcefully intruded into the mafic metavolcanic sequence, and major folds adjacent to the complex were deformed and crossfolded (Fig. 9). Contacts with country rock are subvertical and are generally sharp although diorite, tonalite, and syenite locally form an intrusion breccia with mafic metavolcanics. Metavolcanic inclusions and screens occur throughout the complex but are not abundant.

A contact metamorphic aureole ranging in width from 1,000 to more than 10,000 feet is superimposed on the regional metamorphism. Most screens and inclusions, and rarely country rock immediately adjacent to the complex are in the pyroxene hornfels facies; the remainder of the aureole is in the hornblende hornfels facies.

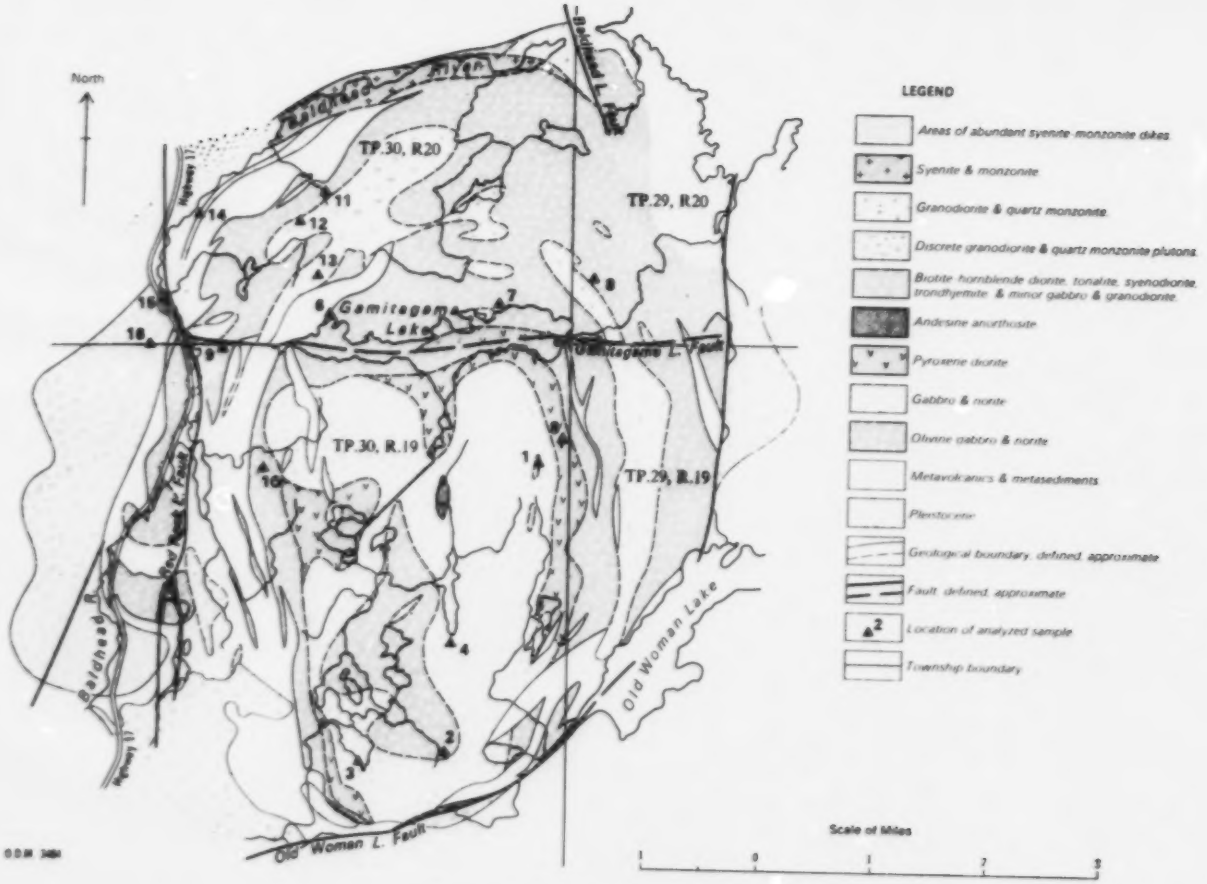

Figure 4 — Gamitagama Lake Complex.

Table 3 *Analyses of specimens taken from Gamitagama Lake Complex. (See Figure 4 for locations of samples.)*

Analysis Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sample Number	61-P-74-2	61-A-684-2	61-A-691-1	61-A-678-1	61-A-142-2	61-P-30-3	62-A-134-2	62-A-128-1	63-35	61-A-278-1	62-J-23-1	62-A-75-1	62-A-77-1	62-A-104-1	62-A-7-1	61-P-3-3
CHEMICAL ANALYSES																
SiO_2	47.1	47.8	51.6	46.6	52.2	53.5	50.0	57.0	54.5	54.0	59.6	66.6	71.5	75.2	64.5	64.7
Al_2O_3	9.28	14.9	16.3	16.3	17.2	18.1	16.4	18.1	17.9	22.6	14.2	15.5	14.9	13.4	17.2	19.2
Fe_2O_3	0.63	1.68	1.58	6.67	0.85	2.72	2.12	1.88	1.21	2.29	2.56	1.05	0.92	0.50	0.77	1.08
FeO	13.48	9.55	7.04	8.60	8.15	8.27	9.81	4.94	7.40	5.18	6.14	3.58	1.71	0.84	2.61	3.50
MgO	19.9	10.30	6.80	5.05	4.98	3.75	3.53	1.98	3.18	1.64	1.98	1.43	0.54	0.10	0.54	0.34
CaO	8.45	8.47	9.28	10.1	8.10	7.14	7.60	6.68	7.75	4.75	4.78	3.88	1.68	0.63	1.40	1.26
Na_2O	1.08	2.33	2.53	2.29	3.91	3.72	3.98	3.98	3.17	5.64	4.55	4.26	3.98	4.05	4.38	5.38
K_2O	<0.05	0.51	0.30	0.68	1.20	1.81	1.08	1.45	0.73	1.55	1.96	2.73	3.80	5.18	6.73	6.60
H_2O+	0.20	0.85	0.54	0.84	0.61	0.75	0.83	1.14	0.90	1.06	0.85	0.55	0.47	0.28	0.68	0.48
H_2O-	0.12	0.01	0.19	0.22	nil	0.21	0.04	0.04	0.20	0.23	0.06	0.24	0.22	0.03	0.25	0.18
CO_2	0.02	0.27	0.42	0.37	0.38	nil	0.16	0.30	0.24	0.37	nil	0.18	0.08	nil	0.20	nil
TiO_2	0.73	0.71	0.80	2.35	1.03	1.85	2.85	1.59	1.60	1.33	1.31	0.74	0.51	0.29	0.40	0.62
P_2O_5	0.04	0.22	0.05	0.07	0.16	0.28	1.02	0.37	0.31	0.30	0.35	0.16	0.08	0.02	0.07	0.02
S	nil	0.16	0.11	0.20	0.24	0.12	nil	0.21	0.11	0.04	nil	0.19	0.15	0.16	0.14	nil
MnO	0.25	0.16	0.13	0.13	0.16	0.17	0.17	0.09	0.13	0.12	0.18	0.06	0.05	0.03	0.09	0.15
Total	101.3	98.0	97.8	100.5	99.17	100.6	99.54	99.80	99.3	101.1	98.5	101.16	100.59	100.7	99.96	101.3
Specific Gravity	3.19	3.01	2.91	3.01	2.87	2.88	3.03	2.71	2.75	2.74	2.77	2.67	2.63	2.59	2.63	2.64
TRACE ELEMENTS (in parts per million)																
Ba	100	100	100	200	2000	4000	600	400	300	2000	300	200	100	100	100	100
Cr	150	30	200	10	60	5	<10	10	20	<10	<10	10	<10	<10	<10	<5
Co	120	70	60	70	40	20	30	30	40	20	20	10	<10	<10	10	<10
Cu	120	100	300	200	80	30	40	60	120	80	60	80	30	20	40	10
Pb	<10	<10	<10	<10	<10	10	<10	<10	15	<10	<10	<10	<10	<10	<10	150
Ni	1000	200	150	70	70	10	10	20	30	10	10	10	10	10	<10	<10
Sr	60	300	200	300	300	500	400	600	400	300	200	80	20	10	10	30
V	n.d.	200	200	500	200	n.d.	100	100	n.d.	80	80	100	80	40	80	n.d.
Zr	<100	n.d.	n.d.	n.d.	n.d.	300	n.d.	n.d.	100	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2000
n.d. not determined																
MODAL ANALYSES																
Plagioclase	17.8	53.7	75.5	61.3	64.0	62.8	61.0	68.1	66.1	72.4	57.1	52.7	37.0	42.1	33.8	38.6
Potassic feldspar	...	...	...	...	...	...	...	trace	...	3.5	1.2	8.3	25.6	27.2	53.4	47.0
Quartz	...	...	0.6	...	...	...	0.9	9.1	16.1	0.4	13.4	21.3	30.1	28.5	4.6	4.6
Olivine	15.8	10.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Serpentine	...	trace	trace	trace	...	...	...	...	...	...	...	...	...	...	...	...

Talc	...	tracr	...	...	tracr	...	...	...	...	...	...	...	...	...	...	...	...
Orthopyroxene	27.9	16.5	14.9	6.5	14.7	0.7	5.2	...	...	...	...	...	...	...	...	...	...
Colourless secondary amphibole	...	...	...	...	tracr	...	1.6	...	0.5	3.6	...	...	...	...	...	...	...
Coloured secondary amphibole	tracr	tracr	1.3	tracr	0.4	...	...	0.8	...	...	...	0.1	...	...	...	...	...
Clinopyroxene	7.0	2.0	5.7	17.2	9.1	13.9	1.3	0.8	tracr	1.3	...	tracr	...	...	...	...	...
Primary amphibole	31.2	12.5	0.7	2.2	...	0.3	19.5	8.4	14.1	4.9	13.5	5.0	0.2	...	0.3	6.4	
Biotite	...	3.6	0.8	1.3	11.5	18.4	6.7	10.4	1.5	11.4	12.2	12.0	5.4	0.8	7.1	1.9	
Chlorite	...	tracr	...	0.3	...	...	tracr	...	0.1	...	...	...	0.2	0.6	0.2	...	
Muscovite	...	...	...	...	...	...	...	...	...	...	...	...	...	tracr	...	...	
Pistacite	...	...	...	...	...	...	...	...	tracr	tracr	0.5	0.1	1.1	0.1	tracr	...	
Opaque minerals	0.3	1.2	0.3	11.2	0.1	3.6	2.3	1.7	1.2	3.0	2.1	0.5	0.2	0.5	0.1	0.3	
Apatite	...	0.2	tracr	...	0.2	0.1	1.5	0.3	0.1	0.1	tracr	tracr	tracr	tracr	tracr	tracr	
Zircon	...	...	...	...	...	tracr	tracr	tracr	tracr	0.1	tracr	tracr	tracr	tracr	tracr	0.3	
Sphene	...	...	...	...	...	...	...	...	...	...	tracr	...	tracr	...	...	...	
Allanite	...	...	...	...	...	...	...	...	...	...	tracr	...	tracr	tracr	0.6	0.9	
Plagioclase composition (percent An)	>70	71→52	61→48	86	49→35	55→30	42→28	57→38	47→33	27	41→20	37→22	22→4	23→6	14	7→3	
MOLECULAR NORMS																	
Q	...	...	4.3	3.0	...	0.7	...	9.8	8.6	0.9	11.0	18.3	26.8	27.5	7.5	1.8	
Ab	9.5	22.0	24.0	22.0	36.5	34.5	38.0	37.5	30.0	51.5	43.5	39.5	37.0	37.5	40.5	47.5	
An	19.5	29.0	32.8	33.0	25.2	26.8	23.8	27.0	33.0	19.5	12.2	14.5	7.0	2.5	4.5	6.9	
Or	0.5	3.0	2.0	4.0	7.5	10.5	6.5	9.0	4.5	9.0	12.0	16.0	22.5	30.5	40.0	37.5	
C	...	...	...	...	...	...	...	...	...	4.4	...	...	1.6	...	0.8	0.7	
Di Wo	8.4	4.4	4.2	6.2	4.8	2.8	3.0	0.8	1.4	...	4.0	1.0	...	0.2	...	...	
Di En	6.2	3.0	2.9	4.6	2.8	1.6	1.5	0.5	0.7	...	1.9	0.5	...	0.1	...	...	
Di Fs	2.2	1.4	1.3	1.6	2.0	1.2	1.5	0.3	0.7	...	2.1	0.5	...	0.1	...	...	
Hy En	12.2	13.8	16.5	9.8	5.6	8.8	8.3	5.1	8.3	4.6	3.9	3.5	1.6	0.1	1.4	1.9	
Hy Fs	4.2	5.8	7.7	3.4	4.2	6.8	8.3	3.7	7.9	4.2	4.1	2.9	0.8	0.1	2.8	3.6	
Ol Fo	25.4	9.3	...	...	4.2	...	0.15	...	...	...	...	...	...	...	...	...	
Ol Fa	9.3	3.9	...	...	3.0	...	0.15	...	...	...	...	...	...	...	...	...	
Il	1.0	1.0	0.8	3.4	1.4	2.6	4.0	2.2	2.2	1.8	1.8	1.0	0.8	0.4	0.6	0.8	
Mt	0.6	1.8	1.7	7.2	0.9	2.9	2.3	1.9	1.3	2.4	2.7	1.1	0.9	0.5	0.7	1.1	
Ap	...	0.5	0.3	0.3	0.3	0.5	2.1	0.8	0.5	0.5	0.8	0.3	0.3	...	0.3	...	
Cc	...	0.6	1.2	1.0	1.0	...	0.4	0.8	0.6	1.0	...	0.4	0.2	...	0.6	...	
Pr	...	0.5	0.3	0.5	0.6	0.3	...	0.6	0.3	0.2	...	0.5	0.5	0.5	0.3	...	
Normative plagioclase composition	An_{67}	An_{57}	An_{58}	An_{60}	An_{41}	An_{43}	An_{38}	An_{42}	An_{32}	An_{28}	An_{22}	An_{27}	An_{18}	An_{6}	An_{10}	An_{11}	

ANAL. NO.	SAMPLE NO.	DESCRIPTION
1	61-P-74-2	olivine norite
2	61-A-684-2	olivine norite
3	61-A-691-1	anorthositic norite
4	61-A-678-1	anorthositic gabbro
5	61-A-142-2	orthopyroxene diorite
6	61-P-30-3	clinopyroxene-biotite diorite
7	62-A-134-2	amphibole diorite
8	62-A-128-1	quartz-bearing diorite
9	63-35	tonalite
10	61-A-278-1	oligoclase diorite
11	62-J-23-1	trondhjemite
12	62-A-75-1	granodiorite
13	62-A-77-1	quartz monzonite
14	62-A-104-1	granite
15	62-A-7-1	monzonite
16	61-P-3-3	syenite

Townships 31 and 30

Pyroxene Gabbro and Diorite

The pyroxene gabbro and diorite unit comprises seven rock types, olivine gabbro, olivine norite, norite, gabbro, olivine-bearing diorite, orthopyroxene diorite, and clinopyroxene diorite, which, when compared with the biotite-hornblende diorite unit, are characterized by: (1) low content but common occurrence of primary biotite and hornblende, (2) common absence of quartz and potassic feldspar, (3) high incidence of unzoned plagioclase, (4) lack of discontinuous zoning in plagioclase, and (5) scarcity of reaction textures. The unit forms thirty percent of the complex and is concentrated in Township 30, Range 19 where it is zoned outwards from an olivine norite and gabbro core through a wide zone of gabbro and norite to a narrow discontinuous outer zone of pyroxene diorite (Fig. 4). Contacts between rock types are generally gradational.

The unit is medium-grained, equigranular, massive, and dark-grey to brown on both fresh and weathered surfaces. Mafic minerals form about thirty-five percent of the unit but are most abundant in the olivine-bearing rocks and least abundant in the diorites, many of which contain less than twenty percent mafic minerals. Gabbro is locally spotted because of concentration of mafic minerals in spherical aggregates as much as 1 inch in diameter and 1 to 6 inches apart. An almost imperceptible, approximately horizontal layering caused by slight differences in both pyroxene content and grain size was found in several gabbro outcrops. Near the margins of the unit, the layering, where observed, is subvertical. Layers range in thickness from 1 inch to 3 feet. On the east side of the unit the marginal diorite locally has a subvertical flow foliation.

Andesine Anorthosite

Andesine anorthosite underlies a lenticular area north of Picea Lake and forms rare outcrops in other parts of the complex. It occurs within, and in sharp contact with, pyroxene gabbro and diorite although the mafic mineral content of the anorthosite locally increases towards the contact. The anorthosite is medium-grained, equigranular, massive, and white to pale-brown on both fresh and weathered surfaces.

Biotite-Hornblende Diorite Unit

About fifty-five percent of the stock, dominantly in the north and east, and most of the satellitic intrusions, are composed of a heterogeneous mixture of biotite-hornblende diorite, quartz-bearing diorite, tonalite, calcic granodiorite, oligoclase diorite, syenodiorite, and trondhjemite (Fig. 4). In contrast to the other map units, these rocks are characterized by: (1) variable quartz and potassic feldspar content, (2) colour index between 20 and 40 with a high biotite and hornblende content and low pyroxene content, (3) reaction texture between clinopyroxene and green hornblende, (4) discontinuous zoning in plagioclase, (5) low incidence of unzoned plagioclase, and (6) rapid lateral changes in composition. Contacts between the various rock types in the unit are generally gradational and could not be defined. In general, quartz-poor phases occur near pyroxene gabbro and diorite and quartz-rich phases near leucocratic granodiorite and quartz monzonite. Rare inclusions of pyroxene gabbro and diorite are present.

The unit is medium-grained, equigranular to rarely porphyritic (plagioclase phenocrysts), massive to rarely foliated, and grey, dark-grey, or grey-green on both fresh and weathered surfaces. Rapid variations in grain size are locally present but the grain size of the coarsest unit seldom exceeds one centimetre.

Leucocratic Granodiorite and Quartz Monzonite

Leucocratic granodiorite and quartz monzonite which are characterized by: (1) high quartz content, (2) moderate potassic feldspar content, (3) low colour index, and (4) low hornblende content form about fifteen percent of the complex. On the north and east sides of the stock, large, irregularly-shaped bodies occur within, and are gradational with, quartz-bearing phases of the biotite-hornblende diorite unit (Fig. 4); sharp contacts and mafic-rich inclusions are locally present. Narrow granodiorite-quartz monzonite dikes intrude both the pyroxene gabbro and diorite unit and the biotite-hornblende diorite unit. Most dikes are medium-grained and less than 6 inches wide with sharp, commonly unchilled contacts, but several dikes are as much as 500 feet wide.

Narrow pegmatite dikes which are composed of oligoclase, microcline, quartz, and minor biotite and have a maximum grain size of one inch are commonly associated with, and locally form a marginal phase of, the granodiorite-quartz monzonite dikes. Pegmatite is rare in the larger granodiorite-quartz monzonite bodies and in those parts of the complex where granitic rocks are absent.

The granitic rocks are medium-grained, equigranular to rarely porphyritic, massive to rarely foliated, and light-grey to pink on both fresh and weathered surfaces.

This unit appears to be genetically related to granodiorite-quartz monzonite stocks which occur elsewhere in the map-area (see Table of Formations, opp. p.4).

Syenite and Monzonite

A syenite-monzonite dike with a maximum width of 1,500 feet has intruded both the leucocratic granitic unit and the biotite-hornblende diorite unit at the north edge of the stock (Fig. 4). Contacts are sharp but unchilled, and mafic metavolcanic and plutonic inclusions are locally abundant.

Syenite-monzonite dikes are rare elsewhere in the stock, but east of the stock, on strike with the large dike, narrow syenite-monzonite dikes have intruded both the satellitic stocks and mafic metavolcanic-metasedimentary country rock and underlie 5 to 10 percent of the areas outlined in Figure 4. The dikes are irregular in shape and trend, have an average width of 10 feet with sharp but commonly unchilled contacts, and contain numerous rounded to angular, mafic metavolcanic, plutonic, and metasedimentary inclusions which locally have marked reaction rims. In the metasedimentary tongue in the Belanger Lake anticline, syenite-monzonite was preferentially intruded along contacts between metagreywacke and metaconglomerate units.

The syenite-monzonite is medium-grained, equigranular to locally porphyritic with microcline phenocrysts, massive to foliated, and white to pink on both fresh and weathered surfaces. Foliation is generally restricted to dike margins. Several dikes have 2-inch to 6-inch wide contaminated zones at either one or both contacts which contain 10 to 20 percent quartz, minor muscovite and garnet, and rare tourmaline.

DOM7521

Photo 8 — Tonalite containing mafic metavolcanic (black) and quartz-bearing diorite inclusions; road-side rock cut in southern satellitic intrusion of the Gamitagama Lake Complex, east side of Highway 17, Township 30, Range 19.

Satellitic Intrusions

Two poorly exposed satellitic intrusions, which have a combined area of one square mile, and several smaller intrusions, occur on the west side of the main stock (Fig. 4). These intrusions are highly variable in composition and are dominantly intrusion breccias composed of mafic metavolcanic and metasedimentary country rock, at least four mafic plutonic phases, and several leucocratic plutonic phases; each plutonic phase, except the earliest, intrudes and contains rounded inclusions of earlier plutonic rocks (Photo 8). In order of decreasing age, the identified plutonic phases are: (1) gabbro and hornblende gabbro, (2) hornblende diorite, (3) quartz-bearing diorite, (4) tonalite and trondhjemite, (5) leucocratic, calcic granodiorite, granodiorite, and quartz monzonite, and (6) pegmatite. Pyroxene-rich phases are rare. Intrusion breccias appear to be most complex near the margins of the intrusions. Some of the phases probably represent hybrid magmas.

Lamprophyre

A one-foot wide altered lamprophyre dike composed of albite, chlorite, carbonate, and hornblende intrudes granodiorite and diorite on a small island at the east end of Gamitagama Lake. The lamprophyre may be a late phase of the complex or a younger intrusion.

Origin and Age

Work on the complex is still in progress (1966) but a few suggestions can be made about its origin: (1) The pyroxene gabbro and diorite core appears to have formed by differentiation of a pipe-like body of tholeiitic magma; (2) The biotite-hornblende diorite unit appears to be a hybrid unit formed by addition of a more sodic, hydrous, and siliceous magma; (3) The leucocratic granodiorite and quartz monzonite represents a separate magma that was intruded into the partly consolidated biotite-hornblende diorite unit after consolidation of the pyroxene gabbro core.

The complex post-dates the regional metamorphism, a small, sodic, granitic intrusion (p.20, 21), and the Mijinemungshing Lake Trondhjemite. Granodiorite-quartz monzonite stocks, which appear to be related to the complex, intrude the Rabbit Blanket Lake Trondhjemite and appear to intrude equigranular granitic rocks of the southern batholith.

Quartz Monzonite, Granodiorite, and Granite Stocks

Nine quartz monzonite, granodiorite, and granite stocks (see Table of Formations), which are commonly elliptical in plan and range in surface area from 0.03 to 4.5 square miles, intruded the metavolcanic-metasedimentary assemblage and appear to be genetically related to leucocratic granodiorite and quartz monzonite of the Gamitagama Lake Complex. Except for Keweenawan granophyre, the stocks are the youngest granitic rocks in the map-area.

The granitic rocks are commonly grey to pink on fresh surfaces and white, pale-grey, pale-pink, or pale-orange on weathered surfaces. Grain size ranges from 1 to 5 millimetres and most stocks contain both equigranular and porphyritic phases. Phenocrysts are 5 to 10-millimetre long perthitic microcline except in the Bussineau Lake and Rathwell Lake stocks where they are oligoclase. The stocks are massive except for local marginal foliation. The average composition is 40 percent oligoclase and albite, 28 percent quartz, 24 percent perthitic microcline, 5 percent biotite and chlorite, 1 percent muscovite, and 2 percent pistacite, apatite, allanite, zircon, iron-titanium oxide, and sphene.

Except for the Baldhead River Quartz Monzonite which contains three phases, each stock contains only one granitic phase although this phase is commonly variable in composition. In the Chaillon Lake Quartz Monzonite and Belanger Lake stocks, it is composed of quartz monzonite and subordinate granite; in the Fife Lake Granite, it is granite and rare quartz monzonite; in the Kasubeck Creek Granodiorite, it is granodiorite and minor granite; in the Bussineau Lake Quartz Monzonite, it is quartz monzonite; and in the Rathwell Lake and Gravel Lake stocks, it is granite. Several lines of evidence suggest that the granite was originally granodiorite or quartz monzonite in which primary oligoclase was replaced by albite (p.35, 36).

Contacts are both concordant and discordant but are not well exposed; they appear to be sharp and subvertical and have a narrow chilled margin when intruded into greenschist facies country rocks. Inclusions, contaminated zones, intrusion breccia zones, and granitic sills and dikes in the country rock are rare. Stocks emplaced in greenschist facies terrane commonly have a narrow albite-epidote hornfels or hornblende hornfels facies contact aureole. No aureoles were recognized about the Chaillon Lake Quartz Monzonite and Gravel Lake stock which were emplaced in almandine amphibolite facies country rock.

Townships 31 and 30

The stocks were emplaced in the lower part of the epizone and upper part of the mesozone as defined by Buddington (1959).

Special features of four of the stocks are discussed below.

Baldhead River Quartz Monzonite

Ninety-five percent of the Baldhead River Quartz Monzonite is medium-grained to coarse-grained quartz monzonite, granodiorite, and granite; the remainder is older and younger, fine-grained to medium-grained leucogranite which contains primary albite.

The older leucogranite is porphyritic and forms a partial border zone about 200 feet wide on the west side of the stock near the south end of Slievert Lake. The border zone is intruded and breached by medium-grained to coarse-grained quartz monzonite. Porphyritic leucogranite dikes also occur in metasediments south and west of the border zone. The leucogranite contains medium-grained oligoclase, perthitic microcline, and quartz phenocrysts in a fine-grained groundmass of albite, microcline, and quartz. Rare, bright-red dikes which occur in the country rock seem to contain orthoclase phenocrysts.

The younger leucogranite is most abundant in the western part of the stock and forms fine-grained to medium-grained, equigranular to porphyritic dikes and irregular bodies which intrude the medium-grained to coarse-grained quartz monzonite. The dikes range in width from a few inches to more than 50 feet and their average composition is 31 percent albite-oligoclase, 32 percent quartz, 35 percent perthitic microcline, 1.5 percent biotite and chlorite, and 0.5 percent pistacite, iron-titanium oxide, hornblende, apatite, zircon, sphene, and allanite. Rare, pink pegmatite is associated with the leucogranite.

About 800 feet east of the south end of Slievert Lake an unusual breccia occurs in the granitic tongue which breached the porphyritic border zone. The breccia is at least 50 feet in diameter but the full extent is unknown. Well-rounded fragments which range in diameter from 0.03 millimetre to more than 10 centimetres occur in a very fine-grained, almost cryptocrystalline matrix composed of quartz and potassic feldspar. The fragments form about thirty percent of the breccia and are highly strained and locally granulated. The smaller fragments are quartz but the larger fragments are medium-grained, granophyric, potassic granite. No plagioclase was found in thin section or by X-ray diffraction.

Because neither potassic granite nor granophyric texture were found elsewhere in the Baldhead River Quartz Monzonite, the breccia is probably younger than the stock and may be Keweenawan. It appears to be an explosion breccia.

The eastern part of the stock is in the contact metamorphic aureole of the Gamitagama Lake Complex, but the stock is not metamorphosed and is thus younger than the mafic phases of the complex. Several facts, however, suggest that the stock was intruded into a horizontal temperature gradient set up by the complex and that the age difference between the stock and the complex must be small; the stock may be coeval with the granitic phase of the complex.

(1) The marginal chilled zone is wider on the west side of the stock than on the east side.

(2) Intrusion breccia zones are widest on the east side.

(3) Granitic sills and dikes in the country rock are most abundant on the north and east sides.

(4) Porphyritic dikes are most abundant on the south and west sides (Watson [1964, p.462] has shown that porphyritic granitic dikes associated with

some Caledonian granitic intrusions in Scotland were preferentially emplaced on the cooler side of the intrusions).

(5) Leucogranite dikes are more abundant in the western part of the stock than in the eastern part.

(6) The contact metamorphic aureole is wider and at a higher metamorphic grade on the northeast side than on the west side.

The Old Woman Lake fault forms part of the south contact, and granitic rocks on the south side of the fault south of the Gamitagama Lake Complex may be part of the stock.

Bussineau Lake Quartz Monzonite

This small stock is also in the contact metamorphic aureole of the Gamitagama Lake Complex but is unmetamorphosed. On the west side of the stock, quartz monzonite appears to intrude one of the satellitic intrusions of the complex.

Fife Lake Granite

Much of the western part of this stock is covered by Pleistocene sand and gravel which also cover the northern part of the Buckshot Creek and Gargantua Lake faults where they should transect the stock. Because the fault movement is unknown, the exact relationship between the eastern and western parts of the stock could not be determined.

The stock intrudes the Gargantua Harbour Porphyritic Granodiorite and is probably slightly younger than equigranular rocks of the southern batholith because it forms a distinct entity which has a much smaller range in composition than equigranular rocks of the batholith, and has discordant contacts with metasedimentary country rocks.

Gravel Lake Stock

The stock is slightly recrystallized and the recrystallization appears to be related to movement on nearby faults. Pink pegmatite forms about two percent of the stock; pegmatite is rare in the other stocks.

Granite, syenite, and quartz monzonite dikes form about twenty-five percent of the country rock between the Gravel Lake stock and the Chaillon Lake Quartz Monzonite but are rare elsewhere along the contacts of these stocks. The stocks are probably connected at depth.

Unmetamorphosed Ultramafic Dikes

Four, 2 to 5-foot wide, equigranular, medium-grained, unmetamorphosed but partly altered pyroxenite and peridotite dikes with sharp, straight contacts were found in the mafic metavolcanics, and post-date the regional metamorphism. Both clinopyroxene and olivine form tabular oriented grains.

ALBITIZATION

In most of the granite in the map-area, the albite appears to be secondary and to have replaced a primary oligoclase or oligoclase-andesine. Similar secondary albite occurs in some syenite, in almandine amphibolite facies rocks which were retrograded to the greenschist facies, and in some low grade greenschist facies

rocks, especially those in the Cape Chaillon fault block. The albite is similar in size and shape to the primary plagioclase, has bent and wedge-shaped albite twin lamellae while oligoclase has straight lamellae of uniform width, and is always altered to, or replaced by, 0.01 to 0.02-millimetre grains of a colourless, micaceous mineral (possibly fleck sericite of Robertson [1962]) which, unlike other more common plagioclase alteration products, does not mask the twin lamellae. The replacement probably occurred during the deuteric state of crystallization.

The following features indicate that the albite is secondary: (1) relic oligoclase grains which are partly replaced by albite are rarely found in the granite; (2) when both albite and oligoclase occur in the same grain, (a) albite cuts across zoning in the oligoclase, (b) the contact between the two minerals is sharp and irregular, (c) the oligoclase is unaltered or is slightly altered to a very fine-grained brown aggregate, and (d) the albite contains the colourless, micaceous mineral described above; (3) except for plagioclase composition, granite is identical in composition to granodiorite or quartz monzonite which occur in the same intrusion; (4) alteration of biotite to chlorite is more intense in granite than in granodiorite or quartz monzonite.

In some of the albitized rocks and in many unalbitized granitic rocks in the map-area, biotite and chlorite contain narrow lenses, parallel to the cleavage, of very fine-grained potassic feldspar. The lenses probably formed during alteration of biotite to chlorite (Chayes 1955).

METAMORPHISM

The volcanic-sedimentary assemblage was regionally metamorphosed, and the grade of metamorphism varies from low greenschist to middle almandine amphibolite facies (as defined by Fyfe *et al.*, 1958) reflecting systematic changes in metamorphic conditions throughout the area. Greenschist facies rocks are found in the Cape Chaillon fault block, the northeast third of Township 31, Range 20, the central and southwestern part of Township 30, Range 20, the extreme eastern part of Township 31, Range 19, and the western part of Township 30, Range 19 north of the Old Woman Lake fault. Intrusions superimposed contact metamorphic aureoles, which vary from the albite-epidote hornfels to the pyroxene hornfels facies, on the regionally metamorphosed terrane.

In the lower part of the greenschist facies, primary mineralogy and texture are preserved only in actinolite and biotite-bearing carbonate-poor and chlorite-poor rocks which appear to have formed under low partial pressure of CO_2. When the partial pressure of CO_2 was high, carbonate and chlorite are abundant and primary mineralogy is commonly destroyed; in mafic metavolcanics primary texture is also destroyed.

Keweenawan

In order of decreasing age, the Keweenawan System in the map-area is represented by 1,800 to 2,700 feet of Middle Keweenawan basalt, conglomerate, and rhyolite; numerous Middle to Late Keweenawan diabase dikes; and two Middle to Late Keweenawan alkalic syenite dikes.

MIDDLE KEWEENAWAN

The lavas and conglomerate at Cape Gargantua are probably equivalent to part of the Portage Lake lava series in Michigan (White *et al.* 1953) and to part of the North Shore volcanic group in Minnesota (Grout *et al.* 1959), but no correlation will be attempted. Six unnamed members have been recognized: lower basalt, lower conglomerate, middle basalt, upper conglomerate, upper basalt, and rhyolite (Fig. 5).

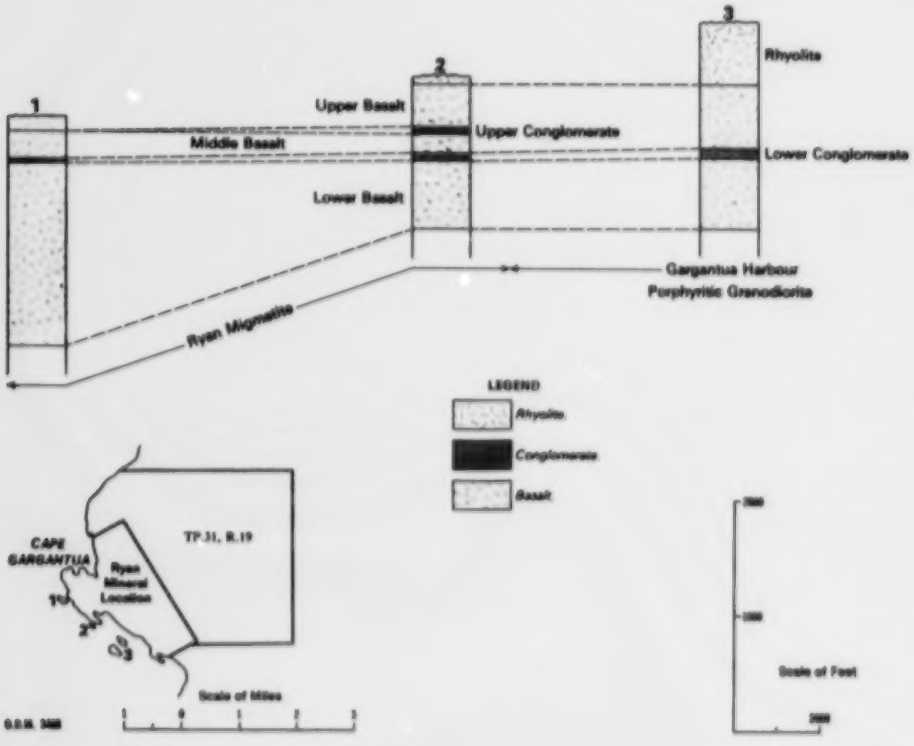

Figure 5 — Columnar sections of Middle Keweenawan volcanic sequence.

Brief descriptions of the sequence at Cape Gargantua were given by Bigsby (1824a; 1824b), Logan (1846; 1847), Agassiz (1850), Logan *et al.* (1863), Bell (1876), Coleman (1899), and Horwood (unpublished report, 1942).

Thickness and Distribution

Between 1,800 and 2,700 feet of basalt, rhyolite, conglomerate, and sandstone unconformably overlie the Ryan Migmatite and Gargantua Harbour Porphyritic Granodiorite near Cape Gargantua in the Ryan Mineral Location. Thickness

estimates are hampered by lack of a continuous section because much of the sequence occurs on islands. Shoreline exposures are excellent, but inland the outcrops are deeply weathered.

In Township 31, Range 20, the author found one small rhyolite outcrop in fault contact with metasediments at the mouth of the Red Rock River. Extensive exposures of Keweenawan volcanic rocks, which were shown by Coleman (1906, Map 15b) in this township along the shore of Lake Superior near the mouth of the Red Rock River and near the Range 21–20 boundary, were not found by the author.

Middle Keweenawan volcanic rocks also occur along the shore of Lake Superior about two miles south of the map-area (Coleman 1899; A.C.R. 1964a).

Basalt Members

Lithology

The mafic flows are dominantly basalt but some andesite is present. The three basalt members are generally similar; differences are shown in Table 4.

Table 4 | *Comparison of lower, middle, and upper basalt members*

	LOWER BASALT	MIDDLE BASALT	UPPER BASALT
Thickness (feet)	600–1600	170–235	365
Composition (based on limited data)	andesite-basalt	basalt	basalt
Dominant texture	equigranular to porphyritic	ophitic	ophitic
Dominant amygdule and vein minerals	silica, calcite, serpentine	calcite, zeolite minerals	calcite, zeolite minerals
Red flow tops and jasper lenses	rare	common	common
Crevice fillings	rare	common	common

The flows are various shades of red, brown, grey, and black; the colour depends on rock composition, composition of amygdule minerals, degree of alteration, and degree of oxidation. There are four main textural types of flows: (1) equigranular or intergranular, in which the grain size seldom exceeds one millimetre; (2) ophitic, in which anhedral, ophitic clinopyroxene is as much as one centimetre in diameter; (3) porphyritic, in which subhedral plagioclase and clinopyroxene phenocrysts are as much as two millimetres long; and (4) glomeroporphyritic, in which tabular plagioclase phenocrysts as much as three centimetres long are concentrated in 3 to 5-centimetre diameter, spherical aggregates. Glomeroporphyritic flows were found only east of Hursley Island in the lower basalt member.

The approximate range in composition is: 25 to 45 percent plagioclase; 0 to 40 percent clinopyroxene; 5 to 15 percent iron-titanium oxide and hematite; 0 to 40 percent unidentified mesostasis which contains abundant ferric oxide; 5 to 50 percent calcite, saponite, zeolite, and hematite which replace clinopyroxene,

plagioclase and mesostasis; and trace to 30 percent amygdule and vein minerals which are calcite, saponite, chlorite, quartz, cryptocrystalline silica, agate, hematite, heulandite, thomsonite, gonnardite, and stilbite.

Plagioclase is subhedral, tabular, high temperature andesine-labradorite which has normal and rare oscillatory zoning. Oscillatory zoning is common only in glomeroporphyritic plagioclase; the high temperature structure was determined by the method of Noble (1965). Plagioclase is locally replaced by calcite, chlorite, saponite, and zeolites. Clinopyroxene varies from intergranular to ophitic and is partly to completely replaced by saponite and calcite.

Most vesicles have been completely filled with secondary minerals, and the resulting amygdules are composite with the minerals arranged in concentric zones; some amygdules contain at least six minerals. Chlorite and saponite commonly occur in the outer part of amygdules, and zeolites, quartz, and calcite occur in the inner part. In red flow tops, amygdules have a hematite rim as much as one millimetre wide. Zeolite minerals are commonly red, probably because of finely disseminated ferric oxide.

Pale-brown to brown saponite, which replaces plagioclase, clinopyroxene, and mesostasis and fills vesicles, is present in most flows and locally forms as much as twenty percent of the flow. Whelan and Lepp (1961) have shown that saponite is a common mineral in Keweenawan basalt along the north shore of Lake Superior.

Structures

Flows range in thickness from several inches to more than 100 feet and average 20 to 30 feet. Many flows are less than 10 feet thick and may be flow units rather than discrete flows. According to Nichols (1936), flow units are lenticular lava tongues which are essentially contemporaneous extensions of a lava flow and overlie the main flow or other flow units from the same flow. Other than the thinness of some flows, evidence indicative of flow units was found only on Hursley Island, where, at the south end of the island, the middle basalt member comprises 12 flows aggregating 180 feet and, at the north end, 2,000 feet along strike, comprises 6 flows aggregating 235 feet.

The upper surface of flows and flow units are similar and can be identified by the following criteria:

(1) Basal amygdaloidal zone (Photo 9). A one-foot thick zone of pipe amygdules occurs at the base of most flows and is commonly separated from a thicker upper amygdaloidal zone by a zone of non-vesicular to poorly amygdaloidal lava. The pipe amygdules begin at the base of the flow and penetrate the basal chilled zone, have a maximum lower diameter of one inch, and decrease in diameter upwards. The lowermost 1 inch to 2 inches of the flow is chilled and contains tiny, spherical to ellipsoidal amygdules. Bent pipe amygdules which can be used to determine the direction of lava flow are rare.

(2) Upper amygdaloidal zone. The uppermost 2 to 10 feet of the flow is highly amygdaloidal and contains as much as thirty percent spherical, ellipsoidal, and irregular amygdules. The spherical and ellipsoidal amygdules have an average diameter of 5 to 10 millimetres and a maximum diameter of 5 centimetres. In thin layers parallel to the flow top, vesicles

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Photo 9 — Contact between two Kewcenawan basalt flows; small island near Hurley Island, Lake Superior. In the upper flow note the tiny spherical vesicles in the basal chilled zone and the large pipe vesicles which penetrate the chilled zone.

have locally coalesced to form vein-like networks and rare tabular vesicles as much as 2 feet long and 1 inch thick.

(3) Red Flow tops. In the uppermost 2 to 3 feet of many flows except in the lower part of the lower basalt member (Table 4), the lava is bright red in contrast to the drab brown, grey, and black of the normal lava. In Michigan, Butler and Burbank (1929) have shown that the red colour is related to an increase in both the total iron content and the Fe_2O_3/FeO ratio and was possibly caused by gases escaping from the lava. The narrow hematite rims on amygdules in the red flow tops indicate mobility of iron and oxidizing conditions. Red colour is partly caused by concentration of red zeolites in the amygdules and mesostasis of the flow tops. A one-inch thick red basal zone was locally found in the flow overlying the lower conglomerate member.

(4) Smooth flow tops. Most flows are pahoehoe and have a smooth but hummocky upper surface with a maximum relief of 6 feet and an average relief of 3 feet; the hummocks are probably tumuli. Because the upper surface is more resistant to wave erosion than other parts of the flow and because flows dip 30 to 45 degrees, erosion has formed small cuestas, the gentler slope of which is the flow surface.

Ropy flow surfaces are found on most smooth-topped flows (Photo 10). Ropes are arcuate to sinuous, ½ inch to 2 inches wide, commonly concentrated in irregular bands several feet wide separated by areas of smooth lava, and oriented perpendicular to the edges of the band. The convex side of arcuate ropes commonly indicates flow direction in the

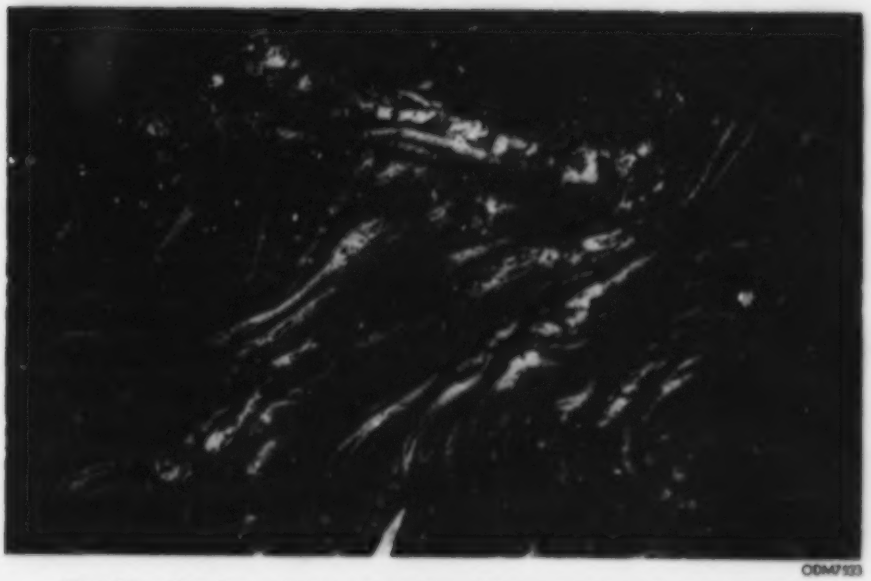

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Photo 10 — Ropy flow surface on a smooth-topped Keweenawan basalt flow; small island near Fawcett Island, Lake Superior.

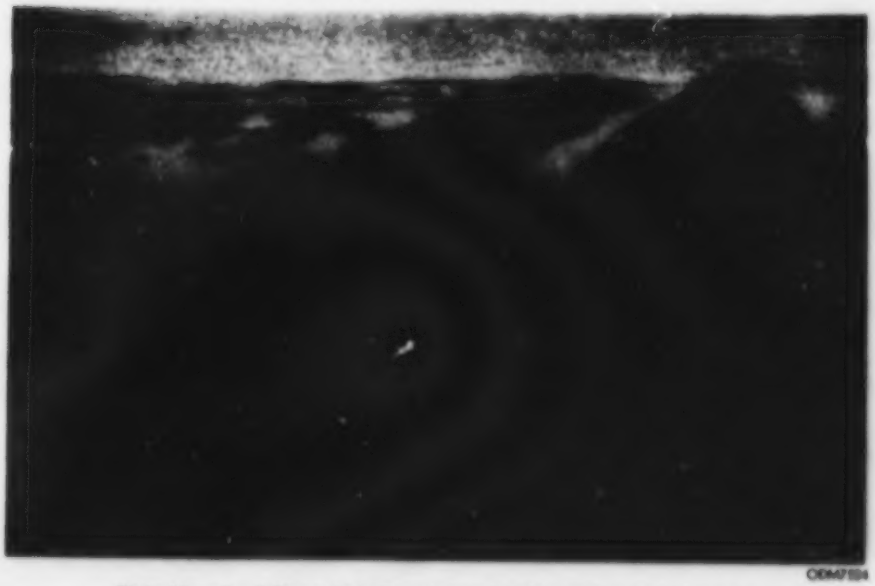

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Photo 11 — Small flow units in Keweenawan basalt; see Figure 6 for location. Note wave-cut platform in upper left corner.

lava, but flow directions determined from ropes are not consistent and appear to be partly related to tumuli. Ropy lava is found as much as three feet below the top of some flows, and buried ropy surfaces may indicate thin flow units.

A small hornito, 5 inches high and 6 inches in diameter was found on a pahoehoe surface on a small island east of Fawcett Island.

(5) Small flow units (Fig. 6; Photo 11). East of Hursley Island, lenticular to pillow-like structures which are intermediate in size between pahoehoe toes (MacDonald 1953) and the original flow units of Nichols (1936) are found in the upper 5 to 15 feet of some pahoehoe flows. These structures range in length from 3 feet to 100 feet and in thickness from 1 foot to 15 feet, and many are larger than typical pillows. (For a description of typical pillows see Shrock [1948].) They have been tentatively classified as flow units although the smaller ones are the same size as pahoehoe toes. Some zones are composed solely of 2 to 4-foot long units which might be true pillows. Amygdules are concentrated in the upper part of each unit, and a ½-inch to 1-inch thick chilled margin is slightly redder than the interior of the flow unit. The lowermost flow units in a zone appear to merge with the underlying lava.

(6) Fragmental flow tops. Fragmental aa flow tops are rare. On the east side of the island north of Pearson Island, a 2-foot thick breccia zone was found at the top of a flow. Fragments range in diameter from a fraction of an inch to six inches but are poorly defined because of replacement by calcite and other secondary minerals, including rare native copper, which form as much as fifty percent of the breccia. Two to three inches of coarse sandstone composed of basaltic detritus and secondary minerals overlie the breccia.

In Michigan, the largest native copper deposits are in fragmental flow tops (Butler and Burbank 1929).

(7) Clastic crevice fillings. Irregular, subvertical (in reference to flow top), dark-red to maroon, clastic "dikes" 1 inch to 8 inches wide were found in the upper part of several flows in the middle and upper basalt members. In thin section, one "dike" contained 50 percent, unidentified, highly altered, rock fragments; rare grains of albite and quartz; 5 percent detrital iron-titanium oxide; 15 percent heulandite; and 30 percent ferric oxide-coated, clay minerals; saponite was identified by X-ray diffraction.

According to Fackler (1941), the "dikes" occupy cooling fractures and were filled from above by weathered, volcanic detritus prior to extrusion of the overlying flow.

(8) Jasper lenses. In the middle and upper basalt members, maroon, jasper lenses which are 1 inch to 3 inches thick, as much as 10 feet long, and parallel to the flow tops are found in the red tops of several basalt flows.

There are several other minor structures which do not define flow tops:

(1) Layering. In the central part of some flows and parallel to the base of the flow are alternating, amygdaloidal and sparsely amygdaloidal layers 1 foot to 2 feet thick which have gradational but abrupt contacts. In glomeroporphyritic flows non-porphyritic, amygdaloidal layers and lenses several feet thick alternate with 5 to 10-foot thick porphyritic, sparsely amygdaloidal layers. The layering probably formed by flow within the lava.

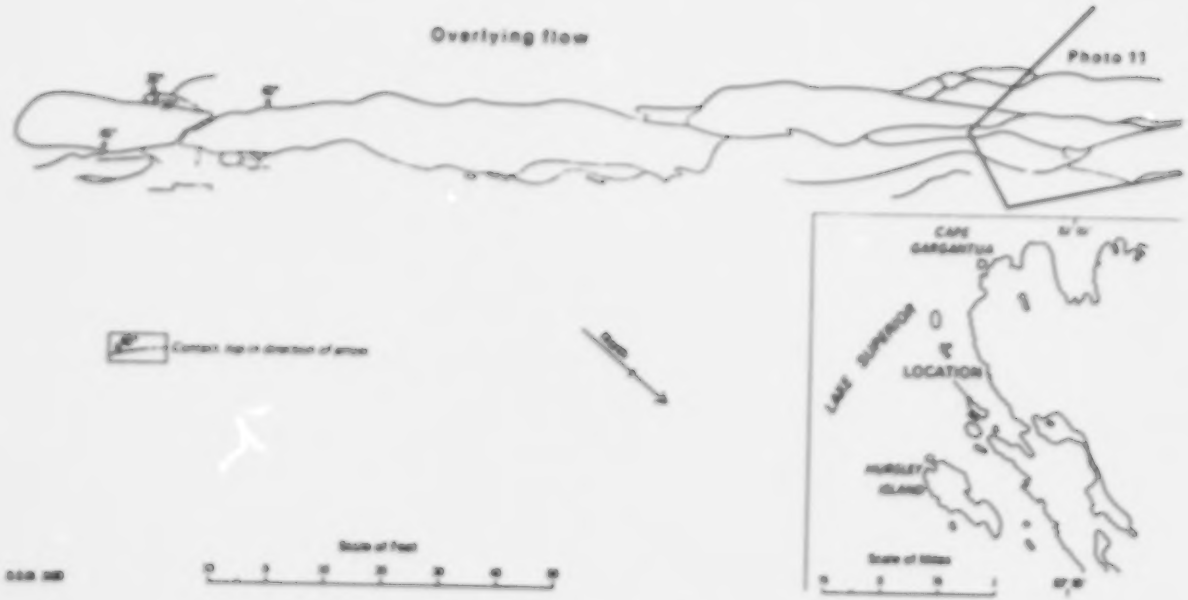

Figure 6 — Small flow units in the upper part of a Middle Keweenawan basalt flow.

(2) Columnar jointing. Columnar joints are poorly developed and are commonly tight; they are rarely occupied by narrow calcite veins. On the west side of Dixon Island, columnar joints in the red top of a middle basalt flow have 1 to 3-inch wide grey reduced borders.

(3) Veins. There are three types of veins in the basalt:

(a) concordant veins which occupy large tabular vesicles and coalescing vesicular networks;

(b) discordant veins which fill branching subvertical (in reference to top of flow) irregular fractures in the upper part of flows and probably occupy cooling fractures;

(c) discordant veins in shear zones.

Vein-filled shear zones with minor displacement occur in most outcrops and form two broad groups:

(a) strike between north and west with a steep northeast dip, and

(b) west strike with a gentle south dip.

Veins are commonly composite and are dominantly composed of calcite, zeolites, and quartz; small but well-formed quartz and calcite crystals are found in some veins.

Conglomerate Members

The lower conglomerate member ranges in thickness from 35 to 60 feet, and the upper member ranges from 8 to 75 feet. Both members appear to form continuous units across the Middle Keweenawan outcrop area. A third conglomerate member was discovered 40 feet below the top of the upper basalt member during diamond-drilling on Devil's Warehouse Island. On the west side of Pantagruel Bay, a two-foot thick sandstone lens was found between two lower basalt flows.

Red-brown polymictic conglomerate contains subrounded to well-rounded pebbles and cobbles of basalt, migmatite, granitic rocks, diabase(?), and agate which have an average diameter of three inches; the largest boulder observed was two feet in diameter. Silt and sand-size matrix forms 25 to 50 percent of the conglomerate and is composed of rounded basalt, cryptocrystalline silica, plagioclase, clinopyroxene, and iron-titanium oxide grains cemented by calcite, hematite, and heulandite which form 10 to 15 percent of the matrix; rare prehnite and pumpellyite were found in the matrix. Eighty to ninety percent of the clastic material in the conglomerate is basalt and minerals derived therefrom.

Two types of basalt which were not found as flows occur as fragments in the conglomerate: (1) light-grey basalt which has 1 to 5-millimetre wide, hematite-rich layers and resembles sandstone; (2) basalt in which primary andesine-labradorite has been partly to completely replaced by albite.

Tabular to lenticular units of coarse sandstone and fine pebble conglomerate which are 6 inches to 5 feet thick and have a maximum pebble diameter of 1 inch form 10 to 30 percent of the conglomerate members. On Hursley Island, six inches of maroon fissile siltstone occurs at the top of the lower conglomerate member.

Conglomerate is thick to very thick-bedded, and sandstone and fine pebble conglomerate are commonly medium-bedded. Cross-bedding was found in the lower conglomerate member on Hursley Island.

The upper contact of both members is well exposed and is a flat, smooth surface. The lower contact is poorly exposed.

Rhyolite

The rhyolite member has a minimum thickness of 550 feet and is well exposed on several rugged, poorly vegetated islands; the top is not exposed.

The rhyolite is characterized by contorted flow layering which is emphasized by alternating greyish-red-purple and white layers. Purple layers form seventy-five percent of the rhyolite and range in thickness from 1 millimetre to 20 millimetres; some purple layers have thin internal laminae which are shown by slight variations in purple colour. White layers have an average thickness of one millimetre, and quartz lenses occur in the centre of some of the thicker white layers. White layers pinch and swell, lens out, and are locally drawn apart, but many layers can be traced along strike for several hundred feet. Ubiquitous flow folds which range in amplitude from less than one inch to tens of feet have not disrupted the continuity of the layers. Rare ovoid vesicles and gas cavities as much as one foot long are filled with quartz crystals, dolomite, and calcite.

Because of the well developed layering, previous workers mistook the rhyolite for sandstone (Horwood, unpublished report, 1942; Johnston and McCartney 1965) or tuff and agglomerate (Coleman 1906).

The rhyolite has a hardness between six and seven, is very fine-grained, and breaks with a conchoidal fracture. The purple layers are composed of granophyric quartz, sodic feldspar, and potassic feldspar which contain 1 to 3 percent oriented, acicular, hematite microlites. The white layers are composed of granophyric to plumose quartz, sodic feldspar, and potassic feldspar which contain 1 to 2 percent equant hematite and 2 to 3 percent biotite. The white layers are coarser grained and contain more quartz than the purple layers. Rare 0.5-millimetre to 1-millimetre phenocrysts of altered feldspar and hematite are oriented subparallel to flow layers. In purple layers hematite microlites are deflected by the phenocrysts. The purple colour is caused by ferric oxide which is dispersed through many of the felsic minerals and by the numerous hematite microlites.

The well-developed layering, the continuity of layers about complex folds, and the flow around phenocrysts in purple layers indicate that the rhyolite is either a lava flow or an intrusive sill but is not an ash-flow tuff (Ross and Smith 1961). At Mamainse, contorted flow layering occurs in intrusive Keweenawan felsite (Thomson 1953), but in the map-area the rhyolite appears to be conformable (Fig. 5) and is probably a flow rather than a sill.

The layering probably formed by laminar flow in the viscous rhyolite magma. Gases and silica were concentrated along planes of more intense flow which became the white layers (Cornwall 1954). In the purple layers, the very fine grain size and dispersion of iron throughout felsic minerals suggest rapid crystallization and possibly devitrification from a glass in which hematite microlites were the only crystalline phase. The white layers probably crystallized from the magma with crystallization being aided by the volatiles which were concentrated during flow. As the magma cooled and became more viscous, continued flow probably formed flow folds.

Closely spaced joints have produced a hackled, weathered surface. Rare, brecciated shear zones trend N25°W and dip steeply northeast. These zones pinch and swell, have a maximum width of 60 feet, and contain trace to 80 percent angular rhyolite fragments in a matrix of calcite and minor hematite, quartz, manganite, and barite. Shear zones are much more abundant in basalt than in rhyolite.

Townships 31 and 30

Table 5 *Analyses of Keweenawan rocks*

Analyses	1	2	3	4	5	6
CHEMICAL						
SiO_2	72.7	75.6		58.4		58.2
Al_2O_3	11.9	12.4		16.7		17.6
Fe_2O_3	0.93	0.97		1.66	4.76	2.21
FeO	0.29	0.30		5.13	3.03	4.63
MgO	0.40	0.42		1.43		0.47
CaO	2.75	0.30	1.02	2.85	1.39	1.79
Na_2O	1.17	1.22	1.64	6.30	5.17	6.70
K_2O	6.59	6.85	5.94	4.58	5.50	5.68
H_2O+	0.72	0.75		1.20		0.79
H_2O-	0.56	0.58		0.57		0.25
CO_2	1.93	n l		0.26		0.56
TiO_2	0.30	0.31		0.90		0.80
P_2O_5	0.02	0.02				0.13
S	0.13	0.14				nil
MnO	0.13	0.14		0.28		0.31
Total	100.5	100.0		100.3		100.1
Specific gravity				2.69		3.12
SPECTROGRAPHIC (in parts per million)						
Ba	600					400
Cr	<10					<5
Co	10					<10
Cu	60					5
Pb	20					400
Ni	10					<10
Sr	30					50
V	100					
Zr						200
NORMS						
Q		39.7				
Or		42.0		27.0		33.0
Ab		11.5		49.5		46.2
An		1.5		3.0		0.5
C		2.8				
Ne				5.1		8.9
Di Wo				3.8		1.6
Di En				1.6		0.4
Di Fs				2.2		1.2
En		1.2				
Ol Fo				1.8		0.7
Ol Fa				2.5		2.3
Mt				1.7		2.3
Il		0.2		1.2		1.2
R		0.1				
Hm		0.7				
Ap						0.3
Cc				0.6		1.4
Pr		0.3				

LOCATION OF SAMPLES

1. Rhyolite, east side of island south of Devil's Warehouse Island.
2. Column 1 recalculated to 100 percent, assuming all CO_2 as secondary calcite.
3. Rhyolite, northwest corner of Devil's Warehouse Island.
4. Alkalic syenite, chilled margin of south dike, Baldhead River, Township 30, Range 19.
5. Alkalic syenite, centre of south dike, Highway 17, Township 30, Range 19.
6. Alkalic syenite, centre of 100-foot wide subsidiary dike north of south dike, Highway 17, Township 30, Range 19.

Chemical analyses are presented in Table 5. The rhyolite contains some secondary calcite, and the complete analysis has been recalculated by assuming that all CO_2 occurred as secondary calcite. The samples are potassic rhyolite.

Rhyolite at Mouth of Red Rock River

At the mouth of the Red Rock River in Township 31, Range 20, a highly jointed and fractured, intensely altered rhyolite outcrop occurs in fault contact with metasediments. The rhyolite is similar to rhyolite near Cape Gargantua except for the presence of: (1) rare quartz phenocrysts; (2) numerous quartz-

calcite lenses and veins; (3) cryptocrystalline silica veins; and (4) spheres, ellipsoids, lenses, and layers of white to pale-green, very fine-grained saponite. The saponite aggregates have a maximum width of three centimetres and a maximum length of ten centimetres and may be altered spherulites.

The outcrop was previously described by Bigsby (1824a) and Coleman (1906, photograph on p.190), and Coleman called it hydrothermally altered tuff and agglomerate. The author has tentatively classified it as a rhyolite flow.

Unconformity

The basalt and conglomerate both dip 30 to 45 degrees southwest because of post-depositional tilting about a northwest-trending axis.

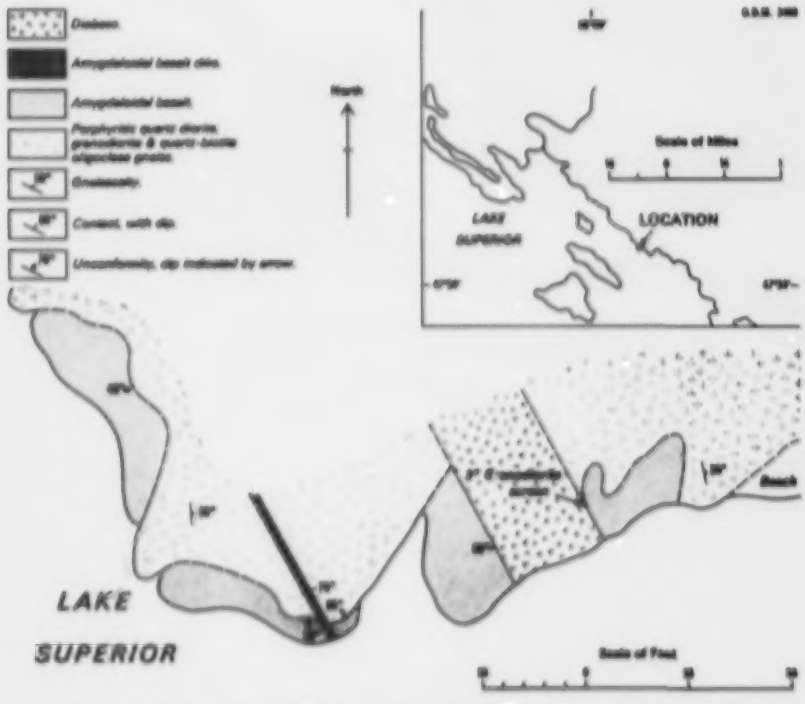

Figure 7 — Unconformity between Middle Keweenawan basalt and the Gargantua Harbour Porphyritic Granodiorite.

The lower basalt member unconformably overlies the Ryan Migmatite and the Gargantua Harbour Porphyritic Granodiorite. The unconformity is well exposed: (1) immediately south of Cape Gargantua; (2) on the east side of Pantagruel Bay; (3) on two islands between Pantagruel and Warp bays (4) on the east side of Warp Bay; and (5) on the mainland east of Dixon Island (Fig. 7). The contact is commonly sharp with no discernible pre-Middle Keweenawan weathering below the unconformity, but, on the south side of the inlier south of

Cape Gargantua, a 6 to 20-inch thick zone of weathered migmatite occurs at the unconformity. On the largest island between Pantagruel and Warp bays, the basal 1 foot to 2 feet of the lowest flow contains angular to subangular pebbles of migmatite, granitic rocks, and quartz.

The pre-Middle Keweenawan surface had a relief of at least 100 feet (Fig. 7), and, if the variation in thickness of the lower basalt member (Fig. 5) is entirely caused by irregularity of this surface, the relief was at least 1,000 feet. The migmatite inlier south of Cape Gargantua was probably a pre-Middle Keweenawan hill.

Because of the relief on the pre-Middle Keweenawan surface, post-depositional tilting has locally overturned the unconformity (Fig. 7).

Basalt Dikes

Fine-grained porphyritic amygdaloidal basalt dikes less than four feet wide are found in the lower part of the lower basalt member and locally can be traced into the underlying migmatite and granodiorite (Fig. 7). The dikes are partly altered and contain clinopyroxene phenocrysts in a groundmass of zoned andesine-labradorite, clinopyroxene, and hematite; amygdule minerals are calcite, chlorite, and saponite.

Metamorphism

The mineralogy of the flow tops is compatible with the zeolitic facies of metamorphism as defined by Fyfe *et al.* (1958). In Michigan, Stoiber and Davidson (1959) consider that albitization, vesicle filling, and replacement of flow tops by secondary minerals occurred during regional hydrothermal metamorphism after tilting of the Middle Keweenawan sequence. In the map-area, the author believes that vesicle filling by hematite and by cryptocrystalline to microcrystalline silica, and at least some of the albitization were deuteric processes related to extrusion. The introduction of calcite, quartz, and zeolites and some alteration probably occurred after tilting.

Four observations suggest the early period of vesicle filling and alteration: the restriction of hematite amygdules to red flow tops; the occurrence of clastic agate pebbles in conglomerate; the occurrence of rare, rounded and broken aggregates of microcrystalline to cryptocrystalline silica in the matrix of the lower conglomerate member; and coexistence in the conglomerate of albitized basalt pebbles, partly albitized basalt pebbles, non-albitized basalt pebbles, and clastic andesine-labradorite grains.

Origin

Middle Keweenawan mafic flows are flood basalts, and the initial dip of both basalt and conglomerate was less than one degree (White 1960). The source of the lava is not known. The presence of granitic and migmatitic fragments in conglomerate indicates that part of the source area for clastic rocks was beyond the eastern edge of the lava.

MIDDLE KEWEENAWAN TO LATE KEWEENAWAN

Diabase

Diabase dikes in the map-area form three sets which, in order of decreasing abundance, trend N31°W with 85°NE dip, N58°W with vertical dip, and N48°E with 80°NW dip. Dikes commonly occupy joints rather than faults, and dike attitudes closely correspond to regional joint sets (Table 9). Northeast-trending dikes predominate over northwest-trending dikes only in areas of east to northeast-trending regional structure such as in Township 30, Range 20 and near the northwest and southeast contacts of the Gamitagama Lake Complex.

Rosiwal analysis of the preliminary maps (O.D.M. maps P.128, P.129, P.174, P.175) shows that diabase underlies two percent of the map-area. In the field, diabase was subdivided into porphyritic and equigranular types. Subsequent petrographic examination showed that most of the equigranular and all of the porphyritic dikes are quartz-bearing diabase. Olivine diabase and diabase which contains neither olivine nor quartz are rare. Dikes of similar composition are found in each of the three sets.

Dikes range in width from a faction of an inch to 300 feet and average about 100 feet, have distinct, microcrystalline chilled margins, and form both linear ridges and linear valleys. Some dikes form ridges in one part of the area but underlie valleys in another part of the area. Positive and negative relief appears to be related to the presence or absence of post-dike shear zones rather than to differences in composition. Commonly ¼-inch to 3-foot wide subsidiary dikes, which locally bifurcate and pinch and swell, occur near, and parallel to wide dikes. In some dikes, joints are well developed both parallel to, and perpendicular to dike contacts.

Contacts are sharp and are commonly straight, step-like, or curved. Step-like contacts result when the dike contact is locally offset by intrusion along an intersecting joint; steps on opposite contacts are commonly similar. When the offset is more than 3 feet, 1-inch to 2-inch wide subsidiary dikes, which are parallel to the main dike, are common at the corners formed by joint intersection. Several subsidiary dikes are more than 20 feet long and must indicate a low viscosity magma. Curved contacts reflect a gradual change in trend of the dike and are commonly sinuous.

Step-like contacts are more common and curved contacts less common in granitic and migmatitic rocks than in metavolcanics and metasediments.

Granitic rocks adjacent to diabase are commonly light pink to red in a zone as much as 50 feet wide. Mafic metavolcanics adjacent to diabase are locally bleached in a 2 to 3-inch wide zone.

Inclusions are rare, are commonly restricted to dike margins, and are seldom more than one foot long. In a road-side rock cut on the west side of Red Rock Lake in Township 30, Range 20, however, numerous, well-rounded but irregularly-shaped, felsic metavolcanic inclusions occur in a 5-foot wide zone in the centre of a 120-foot wide dike. The inclusions have a maximum diameter of 2 feet and are surrounded by a 1 to 2-inch wide zone of contaminated diabase.

Diabase is brown on weathered surfaces and grey to black on fresh surfaces. It is readily distinguished from gabbro of the Gamitagama Lake Complex by its brown weathered surface and lath-like shape of the plagioclase. Grain size ranges from microcrystalline to two millimetres, but rounded to irregular patches of

coarse-grained to pegmatitic diabase occur in several wide dikes. Pegmatitic diabase on the south shore of Villian Lake in Township 31, Range 20 has a grain size of two inches. In fifty-five dikes which were examined in thin section, there are all gradations in texture from intergranular through isogranular and subophitic to ophitic (see appendix for terminology). Ophitic texture was found in 7 percent of the dikes, subophitic texture in 27 percent, isogranular texture in 54 percent, and intergranular in 12 percent. According to most authors, however, the dominant texture in diabase is ophitic.

There is a wide variation in composition among diabase dikes in the map-area, but, because there is also complete gradation, no distinct compositional types could be recognized. Samples from the same dike locally show considerable variation in composition. The approximate composition of quartz-bearing diabase (which forms more than 90 percent of the dikes in the area) is: trace to 9 percent quartz; 45 to 57 percent low temperature zoned lath-shaped andesine-labradorite; 0 to 5 percent granophyric intergrowth of quartz and alkalic feldspar; 25 to 50 percent zoned calcic clinopyroxene and pigeonite; 0 to 10 percent primary blue-green to green-brown hornblende; trace to 10 percent biotite; 1 to 5 percent ophitic iron-titanium oxide which in two polished sections were ilmeno-hematite and ilmenite; and trace amounts of apatite, pistacite, carbonate, pyrite, pyrrhotite, and chalcopyrite. Granophyric intergrowths occur in 65 percent of the dikes. Olivine is rare and where present forms less than 5 percent of the diabase. Orthopyroxene is common in olivine-bearing diabase but is rare in other dikes. Pigeonite is always less abundant than calcic clinopyroxene.

Ten to fifteen percent of the dikes are porphyritic and contain plagioclase and rare clinopyroxene phenocrysts. Plagioclase phenocrysts are equant, oscillatory zoned labradorite-bytownite which have a maximum diameter of 2 inches but average ½ inch. Phenocrysts form as much as twenty percent of the porphyritic diabase but are unevenly distributed and locally form glomeroporphyritic aggregates. Phenocryst-rich zones locally occur near dike margins.

Diabase alteration is patchy: several adjacent grains will be partly to completely altered while nearby grains will be unaltered. The degree of alteration among dikes and within any dike ranges from 10 to 100 percent.

Vugs as much as six inches long which contain quartz crystals and calcite were found in diabase in road-side outcrops along Highway 17 about ½ mile north of the south boundary of Range 19.

Many diabase dikes of all orientations and compositions contain marginal shear zones as much as 20 feet wide which are commonly restricted to the diabase and only rarely enter the country rock. Shear zones occur at either one or both dike contacts but when found at both contacts are better developed at one contact than at the other. In many dikes the outermost several inches of the chilled margin are unsheared. Shearing is not related to diabase intrusion because some shear zones transect small diabase dikes which occur within, and have chilled contacts against, large dikes.

The shear zones commonly contain quartz-carbonate veins as much as six inches wide which locally have comb texture. Minor epidote, chalcopyrite, bornite, hematite, garnet, apophyllite, prehnite, and zeolites are present in some veins. In a road-side rock cut on the west side of Highway 17 about ½ mile north of the south boundary of Range 19, a vein contains calcite, which is locally zoned, quartz, apophyllite, and laumontite.

According to Fahrig *et al.* (1965) and Wanless *et al.* (1965), several ages of diabase occur near the map-area, but the author was unable to subdivide the dikes

on the basis of age. Fahrig *et al.* suggest that all dikes in a set or swarm are the same age. Because intrusive contacts between dikes were only rarely observed, it was impossible to determine the order of intrusion of the three sets or to verify whether the three sets represent different periods of diabase intrusion. Composition is not a valid criterion to determine age because the three major dike sets contain diabase of similar composition. Several dikes appear to be multiple intrusions.

Northwest-trending dikes are younger than the Keweenawan basalt because diabase intrudes the basal part of the Keweenawan sequence (Fig. 7), and because diabase dikes are subvertical but the Keweenawan sequence has been tilted 30 to 45 degrees southwest about a northwest-trending axis from its original horizontal position. Because diabase dikes elsewhere in the Canadian Shield are almost invariably subvertical, northwest-trending dikes should now dip 45 to 90 degrees northeast if they were intruded prior to, or during basalt extrusion. One 8-foot wide dike along the shore of Lake Superior in Range 19 north of Cape Gargantua has a 30 degree northeast dip and is possibly a pre-Middle Keweenawan dike. A contradiction is found north of Fawcett Island where basalt appears to overlie a subvertical, northwest-trending dike. However, exposure is poor and the diabase may intrude the basalt. The northwest-trending dikes may occupy tension fractures which formed during tilting.

Because the northeast-trending dikes are approximately perpendicular to the axis of tilting, their dip would not be affected by tilting, and the relative ages of the Keweenawan basalt and northeast-trending diabase are not known.

The diabase is basaltic and locally andesitic in composition and appears to be compositionally similar to the Middle Keweenawan basalt flows.

Granophyre and Granitic Dikes

Red to grey, fine-grained to medium-grained granophyre with sharp, unchilled contacts was found in five diabase dikes. On the shore of Lake Superior about one mile south of the north boundary of Range 19, a 1-foot wide, pinch and swell zone of granophyre occurs in the centre of a 40-foot wide dike, and a 15-foot wide zone occurs in the centre of a 60-foot wide dike. In the other three dikes, 1-inch to 3-inch wide and 2-inch to 12-inch long granophyre lenses occur in a 1-foot to 2-foot wide zone near the centre of the dikes.

The approximate composition of the granophyre is: 15 percent quartz; 35 percent zoned plagioclase which ranges in composition from albite to labradorite; 15 to 30 percent albite and microcline which commonly form granophyric intergrowth with quartz; 2 percent iron-titanium oxide; 20 to 30 percent amphibole, chlorite, and clinopyroxene; and minor prehnite, pumpellyite, pistacite, allanite, apatite, and carbonate.

Irregular granitic dikes, which are commonly less than three inches wide, were locally found in diabase dikes in granitic and migmatitic terrane. The dikes are fine-grained to medium-grained and equigranular, and, except for the local occurrence of granophyric texture, resemble other granitic rocks in the map-area. They are distinctly different in composition and habit from granophyre and may represent granitic country rock which was partly melted by diabase magma and injected into fractures in the cooling diabase.

Townships 31 and 30

Alkalic Syenite

Two, northeast-trending red porphyritic alkalic syenite dikes occur in the eastern part of the map-area. The south dike has been traced for 10 miles in Township 30, Ranges 20 and 19 and in Township 29, Range 20 (Coleman 1906, p.191) and probably extends into Township 28, Range 21 (Matheson 1933, p.6); it ranges in width from 20 to 100 feet and is well exposed along the Baldhead River and Highway 17 in Township 30, Range 19. The north dike has been traced for six miles in Townships 31 and 30, Range 20 and ranges in width from 10 to 40 feet. Northeast-trending subsidiary dikes ranging in width from 1 to 100 feet are locally present. A 4-foot wide dike was found in the north-central part of Township 31, Range 19. Contacts are sharp but undulate slightly with a maximum amplitude of two feet.

The syenite is greyish-red to reddish-brown on fresh surfaces and reddish-orange on weathered surfaces. Chilled margins are commonly brown to black. The groundmass grain size ranges from cryptocrystalline in the chilled margins to about three millimetres in the centre of the dikes. Phenocrysts are dominantly coarse-grained orthoclase and high temperature oligoclase. The approximate composition of the central part of the dikes is: 1 to 5 percent feldspar phenocrysts; 80 to 89 percent groundmass albite and orthoclase; 8 to 11 percent zoned kataphorite; 1 to 4 percent biotite; trace to 1 percent sphene; trace amounts of clinopyroxene, apatite, hematite, and iron-titanium oxide; and 4 to 8 percent secondary biotite, chlorite, white mica, actinolite, quartz, calcite, leucoxene, and zeolite. Feldspars are commonly oriented and are clouded by dust-like hematite.

Chemical analyses are presented in Table 5. The increase in Fe_2O_3/FeO ratio from the chilled margin to the centre of the dike corresponds to the change in colour from brown to red.

The syenite intrudes northwest-trending diabase dikes and is probably Middle to Late Keweenawan in age. It may be related to alkalic intrusive complexes such as those near Chapleau, Wawa, and Coldwell (Kerr 1910; Parsons 1961).

Paleozoic

CAMBRIAN

Jacobsville Sandstone(?)

Upper Keweenawan to Upper Cambrian, non-fossiliferous to poorly fossiliferous sandstone and associated shale, siltstone, and conglomerate underlie most of the south shore of Lake Superior (Hamblin 1958; 1961) and the east shore between Sault Ste. Marie and Batchawana Bay (O.D.M. Maps P.302, P.303). North of Batchawana Bay isolated exposures are found along the east shore at Mica Bay (Thomson 1953), Alona Bay (Nuffield 1955), and in the map-area (Bayfield 1829; Logan 1846; Herrick *et al.* 1887; Coleman 1906). The sandstone in the map-area is tentatively correlated with the Lower and Middle Cambrian Jacobsville Sandstone in Michigan.

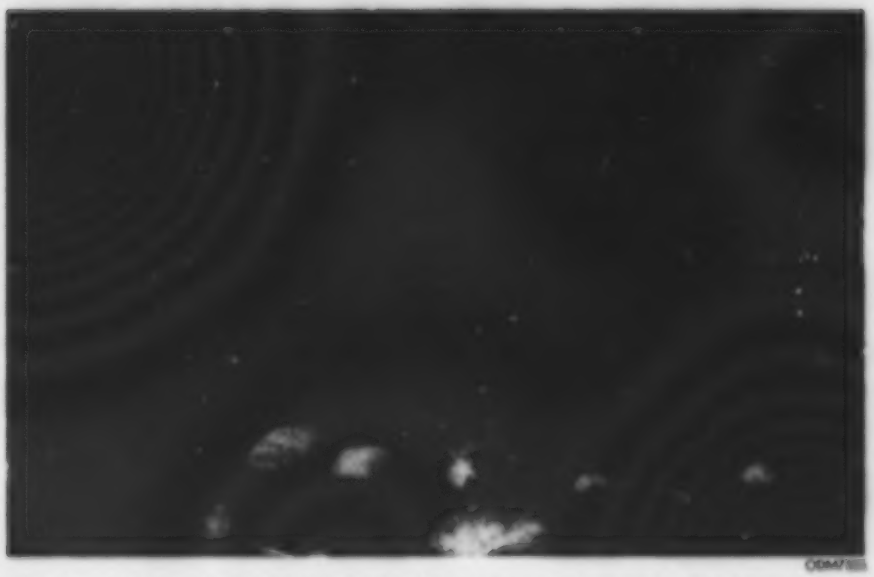

Photo 12 — White and red Cambrian Jacobsville Sandstone showing streaky distribution of colour; northwest side of Grindstone Point, Township 31, Range 20. Note Recent beach deposit in foreground.

Distribution and Thickness

Between 500 and 700 feet of sandstone is exposed in low outcrops at the water's edge and in extensive shoals along the northwest side of Grindstone Point in Township 31, Range 20. Exposure is poor inland. The sandstone is in fault contact with upper mafic metavolcanics and neither the top nor bottom of the section is exposed.

Because sandstone boulders are rare in Recent beach deposits except those developed on sandstone, the presence of abundant sandstone cobbles and boulders in a 1,000-foot long beach about 1,500 feet south of the north boundary of Range 19 suggests that sandstone occurs in shallow water offshore.

Lithology

The section is dominantly white and red sandstone of subarkose, arkose, and subgreywacke composition with minor interbedded siltstone and pebble conglomerate. The approximate composition is: 65 to 85 percent subangular to well-rounded, slightly to intensely strained quartz; 5 to 25 percent rounded to well-rounded microcline which is commonly perthitic; trace amounts of altered plagioclase; 1 to 15 percent rounded rock fragments (dominantly very fine-grained felsic volcanic or sedimentary rocks with minor granitic rocks, granophyre, vein quartz, and chert); trace to 2 percent detrital, bent and broken white mica, biotite, and chlorite; rare detrital zeolite; 5 to 10 percent matrix; and trace amounts of the heavy minerals apatite, garnet, iron-titanium oxide, tourmaline, epidote, and altered amphibole. The matrix is composed of silt-sized quartz and

feldspar, unidentified clay minerals, and secondary white mica and green biotite. In red sandstone all grains are coated by a thin layer of red ferric oxide.

The sandstones commonly show fair sorting but are locally well sorted; fine to medium sand are the most abundant size grades.

White sandstone is more abundant than red sandstone but the two types are intimately intermixed, commonly with a patchy or streaky distribution (Photo 12); streaks are commonly parallel to bedding. Red colour is more abundant in fine-grained sandstone and siltstone than in medium-grained to coarse-grained sandstone. Spheroids and ellipsoids of white sandstone, which locally coalesce to form irregular patches, are present in red sandstone and appear to have formed by reduction of the red sandstone. Tiny fragments of unknown composition are locally found in the centre of the white ellipsoids and were probably the foci for reduction. Red ferric oxide cement is locally concentrated in, or near, fractures.

The very irregular distribution of the red colour suggests that either the red pigment was a primary feature of the environment and was locally removed by reducing conditions and leaching or the red pigment was introduced by oxidizing solutions. The concentration of red pigment in the finer-grained parts of the sequence, and the reduction ellipsoids suggest primary red pigment, but the local concentration of pigment near fractures indicates some post-lithification transport of ferric oxide.

Structures

Bedding ranges from very thin-bedded to thick-bedded but individual beds lens out and can be traced along strike for only short distances. Medium to large scale trough, cross-bedding is well developed, especially in the upper part of the sequence, and individual troughs are as much as 50 feet wide (cross-bedding classified according to McKee and Wier 1953). Grain gradation locally occurs in coarse-grained sandstone.

Eleven current direction measurements from cross-bedding made by Hamblin (written communication, 1964) show an average current direction of N70°W with a range from S65°W to N40°W.

The average dip is 15 to 20 degrees, but adjacent to the Bushy Bay fault the dip steepens to vertical and small drag folds are present.

Metamorphism

The sandstone is unmetamorphosed except adjacent to the Bushy Bay fault where low grade dislocation metamorphism caused the following changes in the sandstone: (1) sandstone is harder and better cemented; (2) bedding is indistinct; (3) red colour is slightly more intense; (4) minerals are granulated along small fractures; (5) microcline grains are locally strained and broken; (6) rock fragments are bent and are locally molded on quartz grains; (7) overgrowth and pitting were observed on quartz grains, the ferric oxide film which coats the detrital grains occurs on the outside of the overgrowth and the inside of the pits; (8) framework is condensed.

Origin

Hamblin (1964) considers that the source areas for most of the Keweenawan and Cambrian sedimentary rocks in the Lake Superior region were near the margins of the present Lake Superior. The abundance of microcline in the sandstone indicates that a large part of the sand was derived from granitic plutons.

Age and Correlation

No fossils were found and the sandstone is in fault contact with other formations, but the low dip and the lack of zeolite facies metamorphism indicate that the sandstone is post-Middle Keweenawan. It is probably correlative with one of the three Upper Keweenawan to Upper Cambrian sandstone formations in northern Michigan, which were formerly collectively referred to as the Lake Superior sandstone (Hamblin 1958), and it most closely resembles the Lower and Middle Cambrian Jacobsville Sandstone. Lithologic similarity, especially when the two units are separated by more than 75 miles, is not a good criterion for correlation, but, because of dissimilarity to the sandstone at Alona and Mica Bays (40 miles south of Grindstone Point) which Hamblin (1961; written communication, 1964) correlates with the Upper Keweenawan Freda Formation, the author has tentatively assigned the sandstone at Grindstone Point to the Jacobsville Sandstone.

Cenozoic

PLEISTOCENE

Pleistocene deposits and land forms in the map-area were probably formed by the Valders ice sheet, which was the final ice advance of the Wisconsin glaciation in the map-area, and by subsequent fluvial and lacustrine action. The Pleistocene geology is shown in Figure 8 (Chart A, back pocket) (*see also* A.C.R. 1964b). Ice retreated from the map-area about 10,000 years ago (Hough 1963).

Direction of Ice Movement

Striations form two sets which trend S37°W and S24°E. Southwest-trending striae are found throughout most of the map-area and probably represent the average movement direction of the last ice advance. Southeast-trending striae are found only near the shore of Lake Superior and are parallel to the shore of the lake and to southeast-trending ridges underlain by Keweenawan diabase dikes and lava flows. They are probably the same age as southwest striae and represent a change in movement direction of the ice sheet rather than a separate ice lobe or glaciation. Striations of intermediate trend are found near the boundary between Townships 31 and 30, Range 19 (Fig. 8).

Drift

Thin drift mantles much of the bedrock, but, below the former Lake Minong shoreline (Fig 8), wave action of prehistoric lakes removed much of the drift from hilltops leaving bare rock hills. Ground moraine and eskers are found only above the limit of the former wave action.

Townships 31 and 30

Thick drift or ground moraine, which has a hummocky surface caused by many kettle holes, locally completely covers the bedrock. The thick moraine deposits are commonly 10 to 75 feet higher than adjacent fluvial sand and gravel deposits and are separated from the fluvial deposits by a 15° to 30° slope. These steep slopes are rare except adjacent to sand and gravel deposits and probably formed by fluvial and locally lacustrine erosion.

South of Chaillon Lake and along the southern part of Buckshot Creek, the contact between the two deposits is approximately coincident with the former Lake Minong shoreline (Fig. 8), and the slope was probably cut by wave action. Along the northern part of Buckshot Creek, north of Gargantua Lake, and west of Highway 17 near the north boundary of Township 30, Range 20, the slope probably formed by erosion by meltwater streams, because present streams within the sand and gravel are underfit.

In the northeast corner of Township 30, Range 20, several terraces are found on moraine hills on both sides of a level sand and gravel plain which fills the valley of Kasubeck Creek (elevation 1,050 feet) (Fig. 8). These terraces were probably cut by a former meltwater stream shortly after ice withdrew from the map-area; Kasubeck Creek is now an underfit stream.

Two 20 to 50-foot high southwest-trending sand and gravel eskers were mapped in Township 30, Range 20, and four short south-trending eskers, which may be parts of a single discontinuous esker, were mapped in Township 31, Range 19. Fluvial and lacustrine erosion along the valley of Buckshot Creek probably formed the gap between the two short eskers in the southern part of Township 31, Range 19. Eskers are best developed on ground moraine.

Fluvial Sediments

Post-glacial, fluvial sediments ranging in thickness from several feet to greater than 150 feet form flat plains in many valleys and are exposed in gravel pits near Highway 17 and locally along roads and streams. The fluvial deposits comprise interbedded, thin-bedded to thick-bedded sand and pebble gravel which locally contain cobbles and boulders. Sorting is poor; grains are subangular to subrounded; cross-bedding is common; and graded bedding and channel deposits are rare (Photo 13). Rare, unidentified, comminuted shell debris was found in coarse sand near the top of a sand and gravel section exposed in a gravel pit west of Highway 17, immediately south of the north boundary of Range 20 (elevation 1,160 feet).

Fluvial sediments are found both above and below the former Lake Minong shoreline and probably began to form shortly after the ice withdrew from the area. Maximum deposition was from meltwater streams, but deposition is still continuing. Dissection of the fluvial sediments by later stream action is common near Lake Superior and was caused by the lowering of the level of the lakes occupying the Superior basin.

Prehistoric Great Lakes

Following withdrawal of the Valders ice, that part of the map-area which is presently adjacent to Lake Superior was inundated by water which had been dammed behind the ice. Detailed descriptions of the prehistoric lakes which

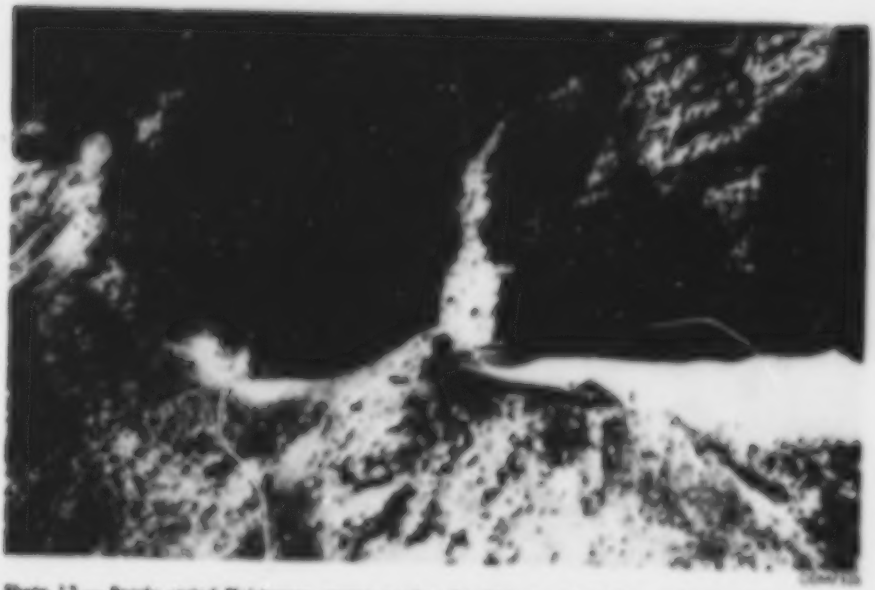

Photo 13 — Poorly sorted Pleistocene, coarse sand and pebble gravel which was deposited in a channel in thin-bedded, fine sand; east side of Boldhead River on trail to property of Coulo Gold Mines Limited, Township 30, Range 19.

occupied the Superior basin have been given by Hough (1958; 1963) and by Farrand (1960; 1962) and will not be repeated here. Postulated elevations of the major lakes in the map-area are given in Table 6. The approximate positions of the Minong, the highest shoreline in the map-area, and Nipissing shorelines are shown in Figure 8. These shorelines were drawn using Table 6 and a contour map prepared by the Ontario Department of Lands and Forests[1].

Table 6 | *Correlation of shoreline features*

ELEVATIONS, FEET ABOVE SEA LEVEL (Level of Lake Superior, 602 ft. A.S.L.)				SLOPE OF SHORELINE (feet per mile)			LAKE STAGES		
Gargantua Harbour		Grindstone Point							
Stanley (1932, Phase IV)	Farrand (1960, Phase VI)	Stanley (1932, Phase IV)	Farrand (1960, Phase VI)	Stanley (1932, Phase IV)	Stanley (1961)	Farrand (1960, Phase VI)	Stanley (1932)	Stanley (1961)	Farrand (1960)
965	955	957	945	3.6	4	3.2	Port Stuart	Minong	
857	845	867	845	2.9		2.9			Minong
	715		715			2.0	crossed		Post-Minong Houghton
684		682		1.2			Pre-Nipissing		
650	640	660	640	0.7		0.8	Nipissing		Nipissing
	630		630	0.6		0.6	Algoma		Algoma
	615		615			0.4			Sault
	610		610			0.3			Sub-Sault

[1] Aerial survey, Lake Superior coast, Batchawana Bay to Michipicoten Harbour, Sheet 4, 1931.

Townships 31 and 30

Measured elevations of former strand lines in the map-area are given by Stanley (1932) and Coleman (1899). Previously unmeasured beaches are summarized in Table 7.

Table 7 — *Elevation of previously unrecorded Pleistocene strand lines (in feet above sea level)*

1	2	3
675	677	900
	669	
	660	
	622	

1. Cave on Devil's Warehouse Island, estimated.
2. Mouth of stream draining Sommers Lake, Township 31, Range 19; aneroid measurements.
3. Terrace along Red Rock River, Township 31, Range 20; estimated from Ontario Department of Lands and Forests Map, Aerial Survey, Lake Superior Coast, Batchawana Bay to Michipicoten Harbour, Sheet 4, 1931.

Beach ridges composed of sand and gravel are the dominant shoreline feature in the map-area; wave-cut benches are rare (Stanley 1932). Much of the sand matrix has been washed from the top of cobble and boulder gravel beaches and vegetation is not well established. Many areas bare of vegetation are found on Nipissing and later beaches of this type.

The Sub-Sault beach, the youngest, pre-Superior beach, is well exposed at Grindstone Point. Rotted pulp logs are found on top of this beach and were probably deposited during a storm on Lake Superior.

One mile north of Gargantua Harbour, a crescent-shaped beach at an elevation of 877 feet (Stanley 1932) trends across, and is the highest topographic feature in a north-trending valley between Gargantua Harbour and the Gargantua River. The beach is about 4,000 feet long and concave to the south; it appears to be a Lake Minong tombolo (Fig. 8).

Horizontal terraces at least one mile long occur at an elevation of about 900 feet along both sides of the Red Rock River valley about 3,000 feet upstream from the mouth of the river (Fig. 8). The terraces are composed of interbedded sand and fine gravel and are probably part of a Lake Minong flood plain or delta which had a maximum width of 2,000 feet but which has now been dissected by the Red Rock River to a depth of 150 feet.

RECENT

Recent sediments are organic mud deposited in swamps; clay, silt, and sand deposited in streams and lakes; and beach deposits along Lake Superior.

Because of the high relief in the map-area, swamps are small and are best

developed on the flat, fluvial, sand and gravel deposits which fill many of the valleys (Fig. 8). Near Highway 17, swamp soundings made by the Ontario Department of Highways show a maximum depth of 23.5 feet and an average depth of less than 5 feet.

Recent fluvial sand and gravel is indistinguishable from Pleistocene fluvial sediments.

The Lake Superior beach is commonly composed of well-rounded granitic cobbles and boulders in a pebble and sand matrix. The matrix has commonly been washed out of the upper part of the beach leaving a boulder and cobble surface (Photo 12). The upper part of the beach is 5 to 10 feet above lake level. Sand beaches have developed only on fluvial sand near river mouths.

Wave-cut benches up to 400 feet wide and between 1 and 5 feet above the level of Lake Superior occur at the northwest end of islands underlain by Middle Keweenawan basalt (Photo 11). Shoals formed by Cambrian sandstone at Grindstone Point are probably an irregular wave-cut bench. Two small stacks were found at the south end of Dixon Island.

Correlation of Geology with Aeromagnetic Data

The map-area was included in an airborne magnetometer survey made in 1962 and 1963, and data for the map-area are shown in O.D.M.-G.S.C. Map 2190G. Except for metamorphosed iron formation, the Gamitagama Lake Complex, and the Keweenawan volcanic sequence, all rock types have approximately the same magnetic intensity although the Rabbit Blanket Lake Trondhjemite in the northeast corner of Township 30, Range 20 has a slightly lower intensity than adjacent metavolcanics. Diabase dikes can only rarely be identified on the aeromagnetic map.

Positive anomalies north of Chaillon Lake, south and west of Belanger Lake, at Red Rock Lake, and near the centre of Township 30, Range 20 are caused by metamorphosed iron formation. A small positive anomaly in the southeast corner of Township 31, Range 20 is probably caused by metamorphosed iron formation, but the area is poorly exposed and no magnetic rocks were found.

The Gamitagama Lake Complex has a high positive magnetic anomaly with the highest part of the anomaly over gabbro and norite which contain about 3.5 percent iron-titanium oxides with an ilmeno-magnetite/hemo-ilmenite ratio greater than two. Pyroxene diorite which contains about 4.5 percent iron-titanium oxides has a slightly lower anomaly than the gabbro and norite because the ilmeno-magnetite/hemo-ilmenite ratio is about one (Balsley and Buddington 1958).

The Keweenawan volcanic sequence has both a positive and negative anomaly with the negative anomaly on the Lake Superior side of the positive anomaly. The anomalies probably reflect the 30 to 45 degree lakeward dip of the sequence (Vacquier *et al.* 1951).

STRUCTURAL GEOLOGY

Foliation, Schistosity, Gneissosity, and Cleavage

Metamorphic foliation which is produced by subparallel orientation of amphibole, biotite, chlorite, muscovite, and rarely plagioclase and quartz is ubiquitous in the metavolcanics and metasediments except in the complexly deformed part of the Desbois Lake syncline in Township 30, Range 19, and in roof pendants in the Gamitagama Lake Complex. The foliation is subparallel to primary flow surfaces and bedding. Foliation which appears to be a primary flow structure is present in many of the intrusions.

Schistosity is rare except in felsic metavolcanics.

Gneissosity produced by metamorphic differentiation occurs in mafic metavolcanics adjacent to (1) the Rabbit Blanket Lake Trondhjemite in Township 30 Range 20, (2) the Gamitagama Lake Complex, and (3) granodiorite of the southern batholith in the southeast and southwest corners of Township 30, Range 19 (p.8, 9). Gneissosity which appears to have formed by shearing is locally present in granitic intrusions. Primary igneous gneissosity was rarely found in the pyroxene gabbro and diorite of the Gamitagama Lake Complex (p.30).

Fracture cleavage which is at a high angle to bedding, flow structure, and foliation is locally present in the felsic metavolcanics. Cleavage is rare elsewhere.

Lineation

Lineation produced by crinkling in schistose rocks, rodding, intersection of cleavage and bedding, minor fold axes, and orientation of amphibole, quartz, and micaceous minerals is found throughout the metavolcanic-metasedimentary sequence (Fig. 9)[1]. Except for minor fold axes, lineation types are not differentiated on the geological maps (2138 and 2139). Minor folds are rare but are more abundant in metasediments than in metavolcanics.

In Range 20, the outcrop pattern of the metavolcanics and metasediments indicates that the Sundstrom Lake syncline and Surf Lake anticline plunge gently to moderately westward. All measured lineations in these folds, however, plunge eastward at about 65 degrees and appear to be *a* rather than *b* lineations. They probably formed by flowage during isoclinal folding. Near intrusions such as the Rabbit Blanket Lake Trondhjemite in Township 30, Range 20 *a* lineations may have formed in response to upward directed forces during intrusion.

In the remainder of the area, most of the lineations are probably *a* lineations although *b* lineations, which are parallel to major fold axes, were measured in the southeast corner of Township 30, Range 19 and locally in Township 31, Range 19 east of Gargantua Lake.

[1]Figure 9 is found on Chart A, back pocket.

Major Folds

There were at least two periods of folding in the map-area: early regional folds, and later cross folds which are related to intrusion of the Gamitagama Lake Complex. The axes of the major folds and the inferred shape of several folds are shown in Figure 9.

The regional folds which comprise the Gargantua Lake anticline, Belanger Lake anticline, Desbois Lake syncline, Surf Lake anticline, Sundstrom Lake syncline, and several unnamed folds are all isoclinal; axial planes commonly dip steeply northeast, possibly because of southwestward tilting during the Keweenawan. Except where cross folds are superimposed, most regional folds have a gentle to moderate plunge.

The Gamitagama Lake Complex either caused distortion of the regional folds and formation of isoclinal cross folds or was intruded into a previously formed domal structure produced by cross folding. The axes of the Surf Lake anticline and the Desbois Lake syncline which are subparallel in Township 31, Range 20 diverge near the complex with the anticline on the north side and the syncline on the west side. Cross folds are best developed on the west side of the complex where the Desbois Lake syncline impinges on the complex (Fig. 9). The axes of the cross folds are approximately parallel to the contact of the complex, and the axial planes dip steeply towards the complex. The shape of the folds, fold pattern, and localization of the folds near the complex suggest that forces associated with intrusion of the complex were the dominant factor in formation of the cross folds although minor cross folding may have preceded intrusion.

Isoclinal folds such as those in the map-area require considerable flowage. The best example of a large flow fold is the bulbous anticlinal cross fold of the Belanger Lake anticline east of Belanger Lake in Township 30, Range 19 (Fig. 9, cross sections). Other than the isoclinal character and outcrop pattern of the folds, the only evidence indicating flowage is the common lenticular shape of fragments in metamorphosed conglomerate, sandstone, pyroclastic breccia, lapillistone and tuff.

There are many features of the rocks, however, which are difficult to explain in terms of the considerable flowage which must have occurred; (1) pillows are only locally distorted; (2) bedding, graded bedding, and other sedimentary structures are well preserved; (3) primary sedimentary and locally volcanic textures are preserved; (4) fragments in metaconglomerate exposed in the sedimentary tongue in the Belanger Lake anticline, which is isoclinally cross folded, are not distorted (Photo 5); (5) schistose zones which might have been zones of intense flow are rare; and (6) pillows and primary texture in mafic metavolcanics are best preserved and foliation most poorly developed in the isoclinally cross folded, isoclinal Desbois Lake syncline in the northwest part of Township 30, Range 19.

Faults

The major faults are subvertical with diverse trends although north-trending to north-northeast-trending faults, commonly with left-hand strike separation, predominate (Fig. 9). Similar faults are the dominant type in the Michipicoten region (Goodwin 1962). Strike separation ranges from a few feet along several

of the small faults to 4.5 miles along the Red Rock River fault; marked vertical offset occurred along some faults, such as the Old Woman Lake fault, Red Rock fault and Red Rock River fault, where blocks with distinctly different metamorphic facies were brought into juxtaposition.

All faults are expressed topographically by negative lineaments and locally by high scarps, and these were used to identify the faults, in conjunction with the following criteria: (1) stratigraphic offset; (2) offset of metamorphic isograds; (3) breccia zones; (4) schistose and locally granulated wallrock; (5) numerous subsidiary faults; (6) alteration of wallrock including retrograde metamorphism, uralitization, epidotization, hematitization, and silicification; and (7) quartz and locally quartz-carbonate or carbonate veins along the fault.

Wallrock alteration is most intense along the north part of the Gargantua River fault and the south part of the Gargantua Lake fault. On the west side of the Gargantua River fault between Chalmers Lake and Cheer Lake in Township 31, Range 20, mafic metavolcanic and locally metasedimentary wallrock is highly epidotized in a zone as much as 2,000 feet wide; the epidotized rock is commonly pale-green to pale-yellow. On the east side of the Gargantua Lake fault south of the Old Woman Lake fault in Township 31, Range 19, almandine amphibolite facies mafic metavolcanics and metasediments are epidotized, silicified, and retrograded to greenschist facies in a zone as much as 1,000 feet wide. Wallrock along the short fault west of Chaillon Lake between the Gargantua River and Red Rock River faults in Township 31, Range 20 is highly altered and sheared and is locally brecciated.

The major faults and the criteria used to identify each fault are tabulated in Table 8. In addition, the presence or absence of quartz veins and sulphide mineralization is noted.

The history of faulting in the map-area is unknown, but most of the economic mineral showings occur along, or are related to, faults. All faults recognized have post-orogenic, brittle movement although the faults may have originated during orogeny. A major fault cuts the Cambrian Jacobsville Sandstone, the youngest formation, and many of the faults were probably active much later than the Cambrian because fault scarps as much as 400 feet high, which are only slightly modified by erosion, are present along many of the faults. The best scarps are along parts of the Bushy Bay, Red Rock River, Gargantua Lake, and Gamitagama Lake faults. In northern Michigan, James *et al.* (1961) have recognized Late Paleozoic(?)-faults, and Hamblin (1958) considers that the Keweenaw fault is probably post-Devonian in age.

There are also many negative lineaments along which no evidence of faulting was found.

Joints

Joints are common in all rock types and form several sets (Table 9) but, because of lack of space, are not shown on geological maps 2138 and 2139 (back pocket).

Joints within the Gamitagama Lake Complex are more scattered than, and some have distinctly different trends from, joints in the remainder of the map-area. The north and N12°E joint sets are parallel to the major axis, in plan view,

Table 8 | *Major faults and their characteristics*

	CRITERIA USED TO IDENTIFY FAULT MOVEMENT							SULPHIDES FOUND ALONG OR NEAR FAULT
	1	2	3	4	5	6	7	
Bushy Bay fault	X			X	X	X		py
Red Rock fault		X		X		X		
Red Rock River fault	X	X	X	X		X		py
Gargantua River fault	X			X		X		
Buckshot Creek fault			X			X		py, cp
Gargantua Lake fault			X			X		
Surf Lake fault	X							
Red Rock Lake fault	X				X			*py, *po
Old Woman Lake fault	X	X		X		X		
Gamitagama Lake fault	X					X		py, cp
Buckhead Lake fault	X							

*In subsidiary faults

SYMBOLS: Q = quartz vein
C = carbonate vein
py = pyrite
po = pyrrhotite
cp = chalcopyrite

CRITERIA:
1. Stratigraphic offset.
2. Offset of metamorphic isograds.
3. Breccia zones.
4. Sphalerite and locally granulated outcrop.
5. Numerous subsidiary faults.
6. Alteration of wallrock including retrograde metamorphism, silicification, epidotization, hematitization, and chloritization.
7. Quartz and locally quartz-carbonate or carbonate veins along the fault.

Table 9 | *Subvertical joint sets, in order of decreasing abundance*

MAP-AREA, EXCLUSIVE OF GAMITAGAMA LAKE COMPLEX		GAMITAGAMA LAKE COMPLEX	
Strike	Dip	Strike	Dip
N30°W	90°	North	90°
N42°W	90°	N34°E	85°NE
N50°E	90°	N12°E	85°E
N12°E	90°	N86°E	87°N
N72°W	90°	N56°W	85°NE
		N24°W	85°SW

of the complex and the N86°E set is perpendicular to this axis. These joints were probably formed by processes related to intrusion of the complex. Diabase dikes in the complex occupy other joint sets which are part of a regional joint system. Joints within other intrusions have the same trend as joints within metavolcanic-metasedimentary formations.

Diabase dikes occupy three of the regional joint sets and some of these joints may have formed by processes related to Keweenawan igneous activity.

Shear joints and joints containing veins are found throughout the area but are not common.

ECONOMIC GEOLOGY

Concentrations of gold, nickel, copper, manganese, iron, sand, and gravel are present in the map-area. Fluorite and radioactive minerals have been reported, but the fluorite occurrences could not be substantiated. Agate and several other minerals including zeolites, apophyllite, and manganite are suitable for mineral collections.

Other than gravel pits opened by the Ontario Department of Highways during construction of Highway 17, there has been no recorded mineral production.

Since 1956 the Provincial Parks Act has prohibited prospecting and staking in the map-area. Three properties in Township 30, Range 19 comprising thirty-eight claims were staked in 1954 and 1955 prior to the present regulations and are currently (1966) held under licences of occupation. The Ryan Mineral Location, a 5-mile by 2-mile area along the shore of Lake Superior west of Township 31, Range 19, was patented in 1866.

The discovery of native copper in Michigan in 1844 initiated mineral exploration in the map-area. In 1846 Thomas Ryan successfully applied for title to a mining location which included most of the Middle Keweenawan volcanic sequence in the area (Logan 1847), and in the same year he transferred title to the Montreal Mining Company. The Canadian government had previously stipulated that mining locations on Lake Superior were to be rectangular areas 5 miles long and 2 miles wide. The mining location is presently (1966) owned by Belco Timber Company Limited. Exploration by several different companies has been carried out intermittently on the mining location for more than 160 years.

In the remainder of the map-area, recorded mineral exploration began in the late nineteenth century with the discovery of chalcopyrite-bearing quartz veins at the west end of Gamitagama Lake, and exploration has continued sporadically since then. The metamorphosed iron formations were first prospected about 1905 (Coleman 1906). Many claims were staked in 1955 following the discovery of gold, nickel, and copper in the Gamitagama Lake Complex.

Quartz Veins

Concordant and discordant quartz veins are found in all rock types in the map-area except in the Jacobsville Sandstone.

Concordant veins, which are commonly discontinuous and less than one centimetre wide, are common in metasediments in all parts of the map-area but are rare in metavolcanics except near large intrusions. Most of the concordant veins probably formed during regional and contact metamorphism.

Discordant quartz veins are as much as 10 feet wide, are commonly subvertical, occupy joints and faults, and are most abundant near major faults. The quartz is commonly anhedral and fine-grained to coarse-grained although subhedral to euhedral quartz is found in a few veins. A large quartz vein near the south end of Belanger Lake in Township 30, Range 19 is green because of fine-

grained clinozoisite and chlorite inclusions. Trace amounts of pyrite are present in most veins; tourmaline, chalcopyrite, and gold are found in rare veins. Carbonate is common in the veins in the Keweenawan volcanic sequence. The larger veins are shown on Maps 2138 and 2139.

Discordant quartz veins formed throughout the entire period of igneous activity. The oldest quartz veins are probably represented by quartz pebbles in metaconglomerate in which all other fragments were derived from a volcanic terrane; the youngest veins cut alkalic syenite dikes.

Gold-bearing Quartz Veins

A gold-bearing quartz vein occurs in a sheared quartz monzonite dike which was intruded along a fault zone in the Gamitagama Lake Complex. In other parts of the map-area, grab samples collected by the author from two chalcopyrite-bearing veins and from four randomly selected, unmineralized veins gave upon assay only trace amounts of gold.

COUTU GOLD MINES LIMITED

History

Coutu Gold Mines Limited (No. 1 on Map 2138) holds (1966) ten claims (SSM40556 to SSM40563 inclusive, SSM41860, and SSM41871) in the northeast part of Township 30, Range 19 under licence of occupation granted in 1963. The claims were staked in 1955 by Wilfred and Edmond Coutu, and in 1958 Coutu Gold Mines Limited was incorporated to obtain the property. If prospecting and staking are ever resumed in Lake Superior Provincial Park, the company will have first chance to stake a 700-acre mining reservation on the south and east sides of the property.

Three showings have been discovered: The south showing in claims SSM40562 and SSM41871 and the main showing in claim SSM40560 (Fig. 10)[1] occur along a fault zone; the north showing on the northwest shore of a small lake in claim SSM40559 is about 150 feet northwest of this fault zone.

In 1955 two shallow pits, about 4 feet by 4 feet in surface dimensions, were sunk on the main showing. Twenty-eight diamond-drillholes with an aggregate length of 3,249 feet have been put down on the property (Fig. 10); 12 of these holes (1,024 feet) were drilled in 1956, 10 holes (1,087 feet) in 1959, and 6 holes (1,138 feet) in 1961. Only two of the holes were drilled on the north showing.

Diamond-drill logs and assays were kindly provided by Coutu Gold Mines Limited. Unless specifically stated, all assays quoted were supplied by the company. Some diamond-drill logs have been filed for assessment work (Files SSM321 and SSM322, Sault Ste. Marie). The property map (Fig. 10 on Chart A, back pocket) was prepared from a geological survey by the author in 1962 and from diamond-drill logs supplied by Coutu Gold Mines Limited.

[1]Figure 10 is on Chart A, back pocket.

Townships 31 and 30

General Geology

The property is underlain dominantly by gabbro and norite of the Gamitagama Lake Complex. Minor olivine gabbro and norite, pyroxene diorite, andesine anorthosite, and quartz monzonite of the complex as well as pyroxene hornfels facies, mafic metavolcanic inclusions are also present. A northeast-trending fault along which gold-bearing quartz veins occur bisects the property.

Main and South Showings

The main and south showings (Fig. 10) are about 600 feet apart and occur along the northeast-trending fault which dips about 60 degrees southeast and is expressed topographically by a valley. Olivine gabbro, olivine norite, gabbro, norite, and mafic metavolcanics are uralitized and locally serpentinized in a 25-foot to 50-foot wide zone on each side of the fault; immediately adjacent to the fault the wallrocks are sheared and locally brecciated, and plagioclase is altered.

Quartz monzonite pods and dikes were locally intruded along the fault and in subsidiary fractures parallel to the fault. At the main showing, a 250-foot long pod occurs near the southeast side of the fault, and a shorter pod occurs 30 feet southeast of the fault (Fig. 10). Both pods have a maximum surface width of 30 feet and thin downward. At the south showing, a discontinuous dike with a maximum surface width of 10 feet occurs along the fault zone (Fig. 10) and appears to widen at depth. No quartz monzonite was found between the two showings.

The quartz monzonite is porphyritic with corroded, oriented, 1-millimetre long, complexly-zoned, oligoclase phenocrysts and rare, anhedral, perthitic microcline phenocrysts in a very fine-grained, sheared and recrystallized groundmass. The phenocrysts are locally strained and fractured but have retained their primary, subhedral shape. The dikes are similar in composition and are probably genetically related to other quartz monzonite and granodiorite dikes in the Gamitagama Lake Complex, although the dikes elsewhere are fine-grained to medium-grained and equigranular, and occupy joints.

Post-consolidation movement along the fault produced fractures in the quartz monzonite along which quartz veins were deposited from hydrothermal solutions.

At the main showing, a quartz vein with an average width of 4 feet and a maximum width of 8 feet occurs 5 to 10 feet southeast of the fault dominantly in quartz monzonite but locally extending into gabbro (Fig. 10); the vein dips 60 degrees southeast and locally contains inclusions of wallrock (Photo 14). The vein has been tested by diamond-drilling to a vertical depth of 200 feet. Other veins, commonly less than one foot wide, occur in the quartz monzonite pod and rarely in the second pod, and in the gabbro between the two pods. Near the quartz veins the wallrock is locally silicified.

The quartz is white, is commonly fractured with the dominant fractures parallel to the vein margins, and locally contains visible gold; no sulphide mineralization was observed. Assays taken across the vein within the quartz monzonite pod range from trace to more than 1.5 ounces of gold per ton, but, when the vein extends into gabbro, it commonly contains less than 0.05 ounces of gold per ton. The minor veins contain only trace amounts of gold. Within the vein there appears to be a 200-foot long by 30-foot wide ore shoot raking 45 degrees southwest. In the shoot the vein ranges in thickness from 0.5 to 7 feet and contains 0.5

Photo 14 — Gold-bearing quartz vein at main showing of Coots Gold Mines Limited, Township 30, Range 19.

to 1 ounce of gold per ton; the shoot does not reach surface. Another high grade section of the vein is at the north pit (Fig. 10; Photo 14) where a chip sample taken by the author across 4.5 feet gave upon assay 1.37 ounces of gold per ton.

At the south showing, a quartz vein, which locally contains carbonate, occurs along the sheared contact between quartz monzonite and gabbro (Fig. 10); at depth the vein is completely within gabbro. The vein dips 60 degrees southeast and has an average width of four feet and a maximum width of seven feet; at surface it is less than two feet wide. Locally, numerous, narrow quartz veins occur in a zone as much as 15 feet wide. Assays are commonly less than 0.05 ounces of gold per ton; the highest recorded assay is 0.25 ounces. Higher assays were obtained when the vein was adjacent to quartz monzonite than when the vein was completely enclosed in gabbro. Nowhere at the south showing is the vein completely enclosed in quartz monzonite.

Narrow quartz veins containing trace amounts of gold were intersected by the two diamond-drillholes between the main and south showing (Fig. 10).

At the showings high concentrations of gold were found only in quartz veins which are within 20 feet of the fault and which are completely enclosed in quartz monzonite dikes and pods. At the main showing the quartz monzonite pod, which at surface is adjacent to the fault and contains the gold-bearing quartz vein, thins at depth and migrates away from the fault. At a vertical depth of about 175 feet, the vein, which is parallel to the fault, passes from the quartz monzonite into gabbro with an apparent decrease in gold content. Other quartz monzonite pods and dikes which might contain gold-bearing quartz veins probably occur at other places along the fault.

Townships 31 and 30

North Showing

The north showing is on the northwest shore of a small lake about 1,000 feet northeast of the main showing and 150 feet northwest of the fault along which the other two showings occur. Narrow quartz veins containing trace amounts of gold are present in both quartz monzonite and gabbro.

Both the extension of the major fault and a large quartz monzonite dike are exposed at the northeast end of the lake about 400 feet from the north showing.

Nickel and Copper

In the Gamitagama Lake Complex, pyrrhotite is the dominant accessory sulphide mineral in gabbro and norite and is present, although less abundant than pyrite, in pyroxene diorite; it is rare or absent in the other phases of the complex. Concentrations of pyrrhotite with associated pentlandite and chalcopyrite are found only in the southern part of the complex in areas underlain by pyroxene gabbro and diorite (Fig. 11); the largest concentrations are at, or near, the southern contact.

Figure 11 — Pyrrhotite-pentlandite-chalcopyrite showings in the Gamitagama Lake Complex.

At the showings (Fig. 11) interstitial aggregates of sulphide minerals which appear to have formed by magmatic crystallization are disseminated throughout the gabbro. Sulphurization may have been an important factor in formation of the

sulphide minerals, but insufficient data are available to determine the exact mode of origin. There is no evidence to support a hydrothermal origin for the sulphide minerals.

Following the discovery of the sulphide mineralization in 1955 most of the southern part of the Gamitagama Lake Complex was staked, but under the terms of the Provincial Park Act only two properties contained sufficient mineralization to be approved by Departmental inspectors.

KEEVIL MINING GROUP LIMITED (RENNER OCCURRENCE)

History

The Renner occurrence (No. *2* on Map 2138) comprises twenty claims (SSM.35153 to SSM.35156, SSM.36666 to SSM.36670, and SSM.44473 to SSM.44483 inclusive). They are at the southwest corner of the Gamitagama Lake Complex in Township 30, Range 19 (Fig. 11) and were staked in 1954 and 1955 by Lawrence and George Renner. Concentrations of pyrrhotite, pentlandite, and chalcopyrite were found in gabbro and pyroxene diorite at six places on the property (Fig. 11), but detailed exploration has been confined to one showing which will be referred to as the main showing. Pyrrhotite, pentlandite, and chalcopyrite were also found in mafic metavolcanic country rock and along the contact between a diabase dike and gabbro.

Four trenches were dug by the Renner brothers: (*1*) on the main showing in claim SSM.36669 (Fig. 12); (*2*) on a small showing in claim SSM.44480 west of Pukkimaki Lake; (*3*) on a small showing in claim SSM.36666 east of the south end of Pukkimaki Lake; and (*4*) along a mineralized contact between diabase and gabbro in claim SSM.44478 (Fig. 12).

In 1955 the property was optioned to Falconbridge Nickel Mines Limited who, in 1955 and 1956, carried out magnetometer, electromagnetic, and geological surveys of selected parts of the property. Sixteen diamond-drillholes with an aggregate length of 7,580 feet were put down on the main showing (Fig. 12, drillhole numbers 1 to 16 inclusive). The option was dropped in 1956.

In 1959 the property was optioned by Empire Explorations Limited, a member of the Keevil Mining Group Limited, who currently (1966) hold the property under licence of occupation granted in 1965. In 1960 the company carried out geological and electromagnetic surveys of the entire property and resistivity, self-potential, magnetometer, and topographic surveys near the main showing. Fourteen diamond-drillholes with an aggregate length of 6,265 feet (Fig. 12) were drilled near the main showing.

The property was briefly described by Thomson *et al.* (1957, p.80), and more data are contained in assessment work files (SSM.323).

The author is indebted to the Keevil Mining Group Limited and Falconbridge Nickel Mines Limited for providing geophysical and geological maps, diamond-drill logs, and assays. All assays quoted were provided by the Keevil Mining Group Limited; some of the drill core was logged by the author. The map of the main showing (Fig. 12) was modified from a geological map and diamond-drill logs supplied by the Keevil Mining Group Limited, supplemented by geological mapping and diamond-drill core logging by the author.

Townships 31 and 30

General Geology

The property is underlain dominantly by olivine gabbro, olivine norite, gabbro, norite, and pyroxene diorite of the Gamitagama Lake Complex, but biotite-hornblende diorite, tonalite, syenodiorite, trondhjemite, granodiorite, and monzonite of the complex, and hornfelsed mafic metavolcanic and metasedimentary country rock are also present (Fig. 11). The mafic metavolcanics belong to both the upper and lower formations. The Old Woman Lake fault is near the southern boundary of the property.

Main Showing

The main showing is in claims SSM.86609 and SSM.86677 (Fig. 12) where pyroxene gabbro and diorite of the Gamitagama Lake Complex are separated from hornfelsed mafic metavolcanic country rock by a 100-foot to 300-foot wide zone of hybrid and contaminated diorite, tonalite, and granodiorite.

Pyroxene gabbro and diorite are medium-grained, equigranular, and massive; the texture is relatively uniform throughout the unit although composition ranges from olivine norite to pyroxene diorite. Mafic metavolcanic inclusions form 5 to 10 percent of the unit and have sharp contacts with the gabbro and diorite.

The hybrid and contaminated zone contains 5 to 20 percent mafic metavolcanic inclusions, has a highly variable composition, commonly with intrusive contacts between different rock types, and has heterogeneous texture which ranges from fine-grained to coarse-grained and from equigranular to massive. Primary hornblende and biotite are abundant, and garnet is locally present. Mafic metavolcanic inclusions have sharp to gradational contacts with intrusive rocks.

The hybrid and contaminated unit is commonly in sharp contact with gneissic hornblende hornfels facies mafic metavolcanics, but locally a zone of intrusion breccia as much as 30 feet wide occurs at the contact. The contact is slightly irregular but has an average dip of 70 degrees northeast. The hybrid and contaminated zone also appears to be in sharp contact with the pyroxene gabbro and diorite unit, but a mineralized zone near the contact masks the precise relationship between the two units. This contact also dips 70 degrees northeast.

Monzonite and syenite dikes ranging in width from a few inches to 30 feet occur in the outer part of the hybrid and contaminated zone and in the mafic metavolcanics. They were not found in the pyroxene gabbro and diorite.

Near the main showing, pyroxene gabbro and diorite commonly contain 0.25 to 1 percent pyrrhotite, pyrite, pentlandite, bravoite, and chalcopyrite. However, within a 1,000-foot long by 150-foot wide area immediately adjacent to the hybrid and contaminated unit, three zones in the pyroxene gabbro and diorite are sparsely mineralized with 5 to 20 percent pyrrhotite, pentlandite, and chalcopyrite (Fig. 12). Within the largest of these zones and immediately adjacent to the hybrid and contaminated unit, a highly mineralized zone contains 20 to 75 percent sulphide minerals.

The sparsely mineralized zones are discontinuous, pinch and swell, are parallel to the contact with the hybrid and contaminated unit, have a maximum width of 75 feet, have been tested by diamond-drilling to a depth of 800 feet, and contain about 0.4 percent nickel and 0.3 percent copper.

The highly mineralized zone is 800 feet long, has a maximum width of 60 feet, and extends to a depth of 300 feet over most of its length. Near drillholes

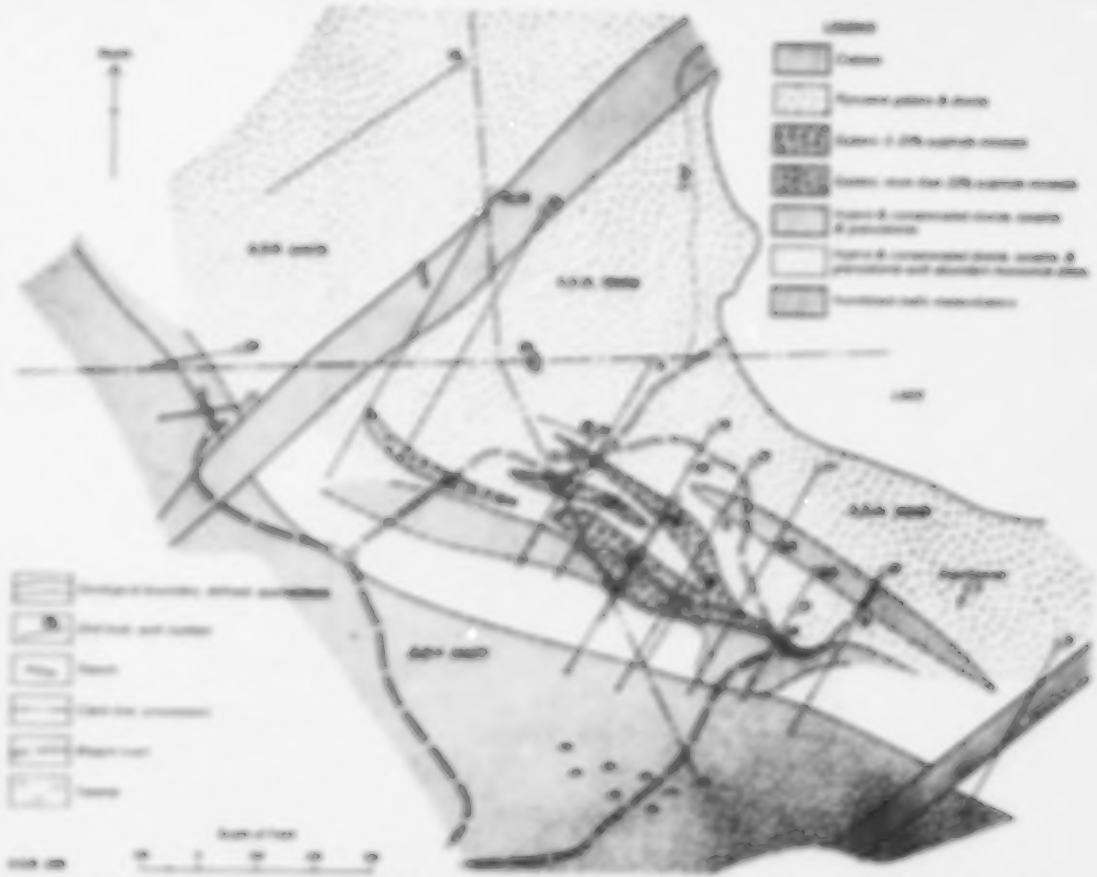

Figure 13 — Plan of main stoping on Beaver Occurrence. (Topography and geology modified from maps and diamond-drillhole data supplied by Victoria Explorations Ltd. Geology supplemented by mapping and diamond-drill core logging by the author.)

24 and 31, however, it appears to plunge about 80 degrees southeast and the top of the zone was intersected in drillhole 23 at a depth of 300 feet. This zone appears to occur where the hybrid and contaminated unit is narrowest (Fig. 12). The zone has an average content of 0.9 percent nickel and 0.6 percent copper, but 10 to 15-foot wide high grade sections within the zone contain 1 to 2 percent nickel and 0.8 to 1.5 percent copper. The highest grade section is immediately adjacent to the hybrid and contaminated unit, and the highest assays in this section seem to be near the top of the mineralized zone. The highly mineralized zone contains trace amounts of gold, silver, and platinum group metals.

The mineralized zones are gradational with pyroxene gabbro and diorite which contain minor amounts of sulphide minerals but are in relatively sharp contact with the hybrid and contaminated unit in which sulphide minerals are rare.

In the sparsely mineralized zones and in the lower grade part of the highly mineralized zone, sulphide minerals form interstitial aggregates in unaltered gabbro and diorite. In the higher grade part of the highly mineralized zone the sulphide minerals predominate and contain silicate inclusions which appear to be unaltered although quartz is locally abundant. Sulphide veins with sharp contacts against gabbro and diorite are rare. Metavolcanic inclusions do not contain sulphide minerals and are in sharp contact with mineralized gabbro and diorite.

In the hybrid and contaminated unit and in monzonite dikes, sulphide minerals commonly form less than 0.5 percent of the rock, and accessory pyrrhotite is more abundant than accessory pyrite. Elsewhere in the complex, these rock types only rarely contain pyrrhotite. Where sulphide minerals are locally abundant, they vary in habit from interstitial aggregates to veins, and sulphide veins are much more abundant in this unit than in pyroxene gabbro and diorite.

In the mineralized zones angular to rounded pyrrhotite, which ranges in size from 0.2 to 2 millimetres, contains rare exsolved blebs of pentlandite within the grains and exsolved flames near grain boundaries. Most of the pentlandite, however, forms aggregates of 0.1 to 1 millimetre grains which occur between pyrrhotite and chalcopyrite and as veins in pyrrhotite. Pentlandite locally forms discontinuous films between chalcopyrite and pyrrhotite, and between adjacent pyrrhotite grains. Chalcopyrite forms irregular grains which are interstitial to pyrrhotite but are commonly separated from pyrrhotite by aggregates or films of pentlandite. Rounded ilmeno-magnetite and ilmenite grains are included in the sulphide minerals. Contacts between silicate minerals and pyrrhotite and pentlandite are smooth with no evidence of replacement, but contacts between silicate minerals and chalcopyrite are highly irregular because of replacement by chalcopyrite. No replacement textures were observed between the different sulphide minerals. Pyrite and bravoite were not found in the mineralized zones but occur in pyroxene gabbro and diorite outside the zones.

Although the precise mechanism of formation and concentration of the sulphide minerals is unknown, the following mineralogical and textural evidence suggests that the sulphides crystallized from the gabbro and diorite magma.

1. All gabbro and pyroxene diorite in the complex, especially in the southern part, contain minor, disseminated pyrrhotite and rare chalcopyrite.
2. In the mineralized zones, sulphide minerals form interstitial aggregates in the gabbro and diorite; veins are rare.
3. Pyrrhotite and pentlandite do not replace silicate minerals; chalco-

pyrite, which is interstitial to the other sulphide minerals, is the only sulphide replacing silicates.

4. In the mineralized zones, silicate minerals, including olivine, are commonly unaltered.
5. Hydrothermal minerals such as quartz are rare.

Hybridization and contamination appear to have aided concentration of the sulphide minerals because sulphides are most abundant adjacent to the hybrid and contaminated zone. Sulphide minerals in the hybrid zone may have been remobilized from pyroxene gabbro and diorite because, although sulphides are less abundant in the hybrid zone than in pyroxene gabbro and diorite, sulphide mineral veins are more abundant. At the present time the hybrid and contaminated unit forms the footwall of the mineralized zone, but its attitude at the time of intrusion and mineralization is unknown. If the Keweenawan tilting which occurred along the shore of Lake Superior affected the complex, the hybrid unit would have originally been the hanging wall.

Other Showings

The other five showings in pyroxene gabbro and diorite on the property (Fig. 11) contain interstitial aggregates of pyrrhotite, pentlandite, and chalcopyrite which commonly form less than ten percent of the rock. These showings are small and have not been seriously explored; no assays are available.

With one exception mafic metavolcanic inclusions and country rock do not contain sulphide minerals. The one exception, which was intersected in drillhole 17 (Fig. 12), is a 5-foot wide zone in mafic metavolcanic country rock immediately adjacent to the hybrid and contaminated unit. The mineralized zone contains about 30 percent pyrrhotite, pentlandite, and chalcopyrite and gave upon assay 1.00 percent nickel and 1.41 percent copper. Mafic metavolcanics near the mineralized zone are altered and contain abundant prehnite and pistacite which suggest hydrothermal alteration associated with formation of the sulphides. The alteration postdates the contact metamorphism.

Veins and disseminations of pyrrhotite, pyrite, and chalcopyrite were found at one place along the contact between gabbro and a diabase dike in claim SSM44478 and are exposed in a trench (Fig. 12). The sulphide minerals may have been remobilized from the gabbro during intrusion of the diabase dike. This is the only sulphide mineral concentration on the property which contains abundant pyrite.

FALCONBRIDGE NICKEL MINES LIMITED

Falconbridge Nickel Mines Limited (No. 3 on Map 2138) has (1966) eight claims (SSM46355 to SSM46362 inclusive) on the east side of the Renner occurrence. The claims were staked in 1955, and a licence of occupation was granted in 1962. In 1955 and 1956 the company carried out geological, magnetometer, and electromagnetic surveys on part of the claim group in conjunction with work on the Renner occurrence which they then held under option.

The claim group straddles the southern contact of the Gamitagama Lake Complex and includes gabbro and norite of the complex, hornfelsed mafic meta-

volcanic country rock of the upper formation, part of the Old Woman Lake fault, and upper mafic metavolcanics and granitic rocks south of the fault. Quartz veins as much as 10 feet wide occur along the Old Woman Lake fault immediately east of the claim group, and may occur on the property.

A small sulphide mineral showing occurs in claim SSM46356 where gabbro and norite locally contain as much as five percent pyrrhotite, pentlandite, and chalcopyrite in interstitial aggregates. Some of the overburden has been removed from the showing, but no other exploration work was observed. No assays are available.

Copper

In the map-area, copper mineralization in greater than trace amounts occurs in four distinct environments: (1) associated with pyrrhotite and pentlandite in the gabbroic phase of the Gamitagama Lake Complex (previously described); (2) in, and associated with, quartz veins and stockworks in fault zones; (3) in quartz-carbonate veins in sheared diabase dikes; and (4) in Keweenawan basalt

COPPER IN FAULT ZONES

Lost Gacie Occurrence

Chalcopyrite-bearing quartz veins in Township 30, Range 20, immediately west of Gamitagama Lake, were discovered in the latter part of the nineteenth century. The occurrence, known locally as the Lost Gacie (A.C.R. 1966a), was connected by trail to Gargantua Harbour. This occurrence is shown in Fig. 13. Although the exact date of discovery is unknown, in 1898 Bell (1898, p.104) was informed that "a good many years ago, a quartz vein said to be large and well charged with copper-pyrites was found and opened by a Mr. T. Fréchette, about fourteen miles east of Gargantua Harbour." Two claims were patented in 1906, one by G. H. Rogers and the other by W. Edy; the Rogers claim was forfeited in 1936 and the Edy claim in 1956. Twenty-four claims were staked in 1954 but lapsed without any exploration work being done. The veins are now on crown land in Lake Superior Provincial Park.

The map shown in Fig. 13 was modified from a geological map and report prepared by W. W. Beaton in 1954 which was submitted to the Department in 1956 (File 83.2-1). Some of the assays are taken from the Report for Discovery (File 83.2-1) which was required for all claims staked in the provincial park between 1945 and 1956. Other assays are from samples collected by the author.

The veins are in the contact metamorphic aureole of the Gamitagama Lake Complex, 900 to 1,600 feet west of the main part of the complex. Mafic metavolcanics which are metamorphosed to the upper part of the hornblende hornfels facies are intruded by small masses of tonalite and granodiorite of the complex (Fig. 13). Contacts shown on Figure 13 are gradational with numerous granitic dikes in the mafic metavolcanics and many metavolcanic inclusions in the granitic rocks.

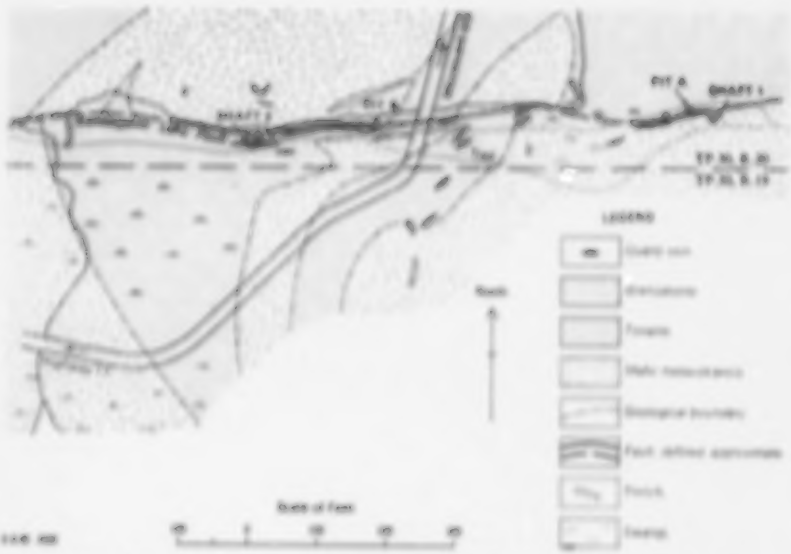

Figure 13 — Plan of Lexi Gneiss Occurrence. This figure is modified from a geological map prepared by W. W. Boston in 1934, supplemented by geological mapping by the author.

Subsequent to the intrusion of the complex, right-hand movement along the Gamitagama Lake fault, an east-trending shear zone approximately perpendicular to the contact of the complex, caused several hundred feet displacement and local brecciation of the wallrock. At the surface the fault zone is occupied by a narrow valley which has high walls on the north side and low walls on the south side.

Hydrothermal solutions, which were possibly derived from the complex, deposited quartz veins in the fault zone and in subsidiary fractures, and caused local silicification of granitic wallrocks. Veins occur as much as 200 feet north and south of the fault zone, but the widest vein, and only vein which could be traced for long distances along strike, is in the fault zone and is exposed on the south side of the fault valley (Fig. 13). This vein pinches and swells and is probably discontinuous; a 100-foot long segment at the east end of the property is separated from a 150-foot long segment at the west end by a 350-foot long gap in which exposure is poor. At the west end of the property, a second wide but short vein occurs 10 feet south of the main vein.

Veins in the fault zone are parallel to the fault and dip 60 to 70 degrees north, but veins outside the fault zone have diverse trends (Fig. 13). The two exposed segments of the main vein average 5 feet in width but have a maximum width of 12 feet. Angular fragments and lenticular horses of country rock are locally present in the veins. Disseminated pyrite and chalcopyrite are present in quartz veins in, and immediately adjacent to, the fault zone and in mafic metavolcanics near quartz veins. The veins are commonly fractured, possibly by late movement along the fault.

Townships 31 and 30

All known exploration work on the veins was done in the latter part of the 19th century and the early part of the 20th century and comprises 2 shafts, 4 pits, and several trenches (Fig. 13). The important work is summarized in Table 10. There is no recorded production from the property.

Table 10 *Major exploration work at Last Gasp occurrence.*

REFERENCE TO FIG. 13	SURFACE DIMENSIONS	DEPTH	WIDTH OF QUARTZ VEIN	COUNTRY ROCK	GRAB SAMPLE ASSAY		COMMENTS
					COPPER	GOLD	
Shaft 1	6' x 6'	15'	[illegible]	mafic metavolcanics with chalcopyrite	1.90%	trace	occurs on top of the south side of the fault valley and has the largest dump of any of the workings. Inward, filled with water.
Shaft 2	5' x 5'	20'	12'	granodiorite	0.60%	nil	occurs on top of the south side of the fault valley and appears to be inside on a vein about 10 feet south of the shaft vein, caved. dump. Inward, filled with water.
Pit A	5' x 5'	5	8'	mafic metavolcanics	1.24%	trace	on bottom of fault valley and against south side.
Pit B	5' x 4'	6	6'	granodiorite	1.64%	trace	
					0.50%	trace	to south side of fault valley.
					trace	trace	

Grab samples collected by Satterly in 1957 (*File 83.2-1*) from two small veins south of the Gamitagama Lake fault gave upon assay 0.38 and 0.10 percent copper; the higher assay was from a quartz vein within mafic metavolcanics.

The limited data available suggest that the largest concentrations of copper occur near the Gamitagama Lake fault in mafic metavolcanics and in quartz veins within mafic metavolcanics. Quartz veins which contain 2 to 3 percent copper when enclosed by mafic metavolcanics contain only a trace of copper when enclosed by granitic rocks.

The occurrence of the copper within the contact aureole of the Gamitagama Lake Complex suggests that the mineralization is genetically related to the complex. Copper mineralization is also found in the contact aureole of the complex in Township 29, Range 20.

Buckshot Creek Fault

Granitic rocks adjacent to the Buckshot Creek Fault are locally intensely brecciated for as much as 20 feet on each side of the fault. The fault is well exposed in an isolated granodiorite outcrop in Township 31, Range 19 about 8,200 feet north of the south boundary and 11,200 feet west of the east boundary of the township. Here the granodiorite fragments and unbrecciated wallrock are highly hematitized, and breccia fragments are cemented by quartz, hematite, and minor pyrite and chalcopyrite; disseminated pyrite is also present in the granodiorite fragments.—A sulphide-rich grab sample taken by the author gave upon assay 2.02 percent copper and a trace of gold while 5 sulphide-poor samples from the breccia contained trace amounts of gold and copper.

A brecciated zone along the fault is also exposed in Township 31, Range 18 on the Beloo Timber Company access road to Gargantua Harbour.

COPPER ASSOCIATED WITH DIABASE

Shear zones as much as 20 feet wide are present at the contact of many diabase dikes (p.50) but are confined to the diabase and only rarely enter the country rock. Calcite and calcite-quartz veins which range in width from a fraction of an inch to six inches are present in the shear zones and locally form stockworks. Chalcopyrite and rare bornite were found in these veins in three diabase dikes along the shore of Lake Superior in Range 19 and in a dike on the west side of Highway 17 about ½ mile north of the south boundary of Range 19. A grab sample collected by the author from a vein in a dike along the shore of Lake Superior about ½ mile south of the north boundary of Range 19 gave upon assay 0.56 percent copper and trace amounts of gold, lead, and nickel.

NATIVE COPPER IN KEWEENAWAN BASALT

Logan *et al.* (1863), Willmott (1898), and Coleman (1899) have reported native copper in the Middle Keweenawan sequence at Cape Gargantua; Willmott, Coleman, and possibly Logan did not observe the native copper in the field but based their descriptions on information given to them by local residents. The author found native copper only on the island north of Pearson Island. Rare, tiny grains of native copper were found there in the fragmental top of an upper basalt member flow (p.42).

In Michigan, native copper is most abundant in fragmental flow tops in which the red colour has been partly destroyed by reduction concomitant with copper deposition (Butler and Burbank 1929). Fragmental flow tops are rare in the Keweenawan basalt at Cape Gargantua (p.42).

In the Middle Keweenawan sequence in Michigan, Stoiber and Davidson (1959) found a secondary mineral zoning to which copper distribution is related; all mines are within the epidote zone, and many mines and areas of abundant copper are at, or near, the boundary of the quartz zone. No epidote was found in the Middle Keweenawan sequence at Cape Gargantua although epidote is a common mineral in the lower part of the sequence in Michigan and at Manitou Point (Stoiber and Davidson 1959). Its absence in the map-area may indicate that the sequence was not deeply buried; epidote might occur down dip.

Other Sulphide Showings

Concentrations of pyrite and pyrrhotite which contain only trace amounts of economically important elements occur in three main environments: (1) along or near fault zones; (2) disseminated in felsic metavolcanics; and (3) disseminated in mafic metavolcanics. Accessory pyrite and pyrrhotite occur in most of the metavolcanics and metasediments in the map-area.

1. Sulphide mineralization along major faults is summarized in Table 8.

Along the Busby Bay fault in Township 31, Range 20, felsic meta-

volcanics locally contain as much as fifty percent disseminated pyrite and trace amounts of gold and copper. Highly sheared mafic metavolcanics along the Red Rock River fault in Township 31, Range 20 contain about ten percent disseminated, euhedral pyrite and trace amounts of copper, lead, and nickel. Many narrow shear zones on the west side of the Red Rock Lake fault are exposed in road-side rock cuts along Highway 17 in Township 30, Range 20. These shear zones are commonly less than six inches wide and contain trace to fifty percent pyrite and (or) pyrrhotite. Grab samples collected by the author from five shear zones gave upon assay trace amounts of copper; one shear zone west of Red Rock Lake contained a trace of molybdenum.

2. On the north limb of the Surf Lake anticline in Township 30, Range 20, about 1½ miles west of Highway 17, rusty-weathering schist layers which were derived from both felsic and mafic metavolcanics occur in the lower mafic metavolcanic and the felsic metavolcanic formations. The rusty-weathering schist layers range in thickness from a few inches to several hundred feet and are confined to a 500-foot thick zone; the schists contain 1 to 10 percent, disseminated, commonly euhedral pyrite. A grab sample collected by the author from a rusty-weathering, felsic metavolcanic schist contained a trace of copper.

   A 10-foot thick unit of rusty-weathering, thinly laminated, felsic metatuff which contains narrow pyrite lenses overlies a pillowed mafic flow in the lower mafic metavolcanic formation on the Mijinemungshing Lake access road in Township 30, Range 20, about three miles east of Highway 17. A grab sample collected by the author from this unit contained trace amounts of copper, lead, nickel, and zinc.

3. In addition to the rusty-weathering mafic schist described above, small lenses of pyrite were found in a mafic metavolcanic inclusion in the Gamitagama Lake Complex in Township 30, Range 19 on the diamond-drill road to the Coutu Gold Mines property. A grab sample collected by the author gave upon assay trace amounts of copper and nickel.

Manganese

Calcite veins containing hematite and manganite occupy fault zones in Middle Keweenawan rhyolite in the Ryan Mineral Location. The widest vein is on Devil's Warehouse Island, and this vein is also reported to occur along the northeast shore of Pantagruel Bay. Other veins are found on Jordan Island and the small island southeast of Jordan Island.

Algoma Ore Properties Limited kindly provided data about exploration work on the veins.

DEVIL'S WAREHOUSE ISLAND

The vein on Devil's Warehouse Island has been known since at least 1860 when it was mentioned in the survey notes of T. W. Herrick,[1] and exploration has been carried out intermittently for about 100 years. In 1910 twelve trenches (Fig. 14) ranging in length from 30 to 70 feet were dug, and two diamond-drillholes with an aggregate length of 835 feet were put down. Other holes were reportedly drilled between 1936 and 1942 (Horwood 1942, unpublished report) but the author could find no record of these holes. The vein is briefly described by Horwood and by Johnston and McCartney (1965, p.29).

Figure 14 — Plan of manganese showing on Devil's Warehouse Island, Lake Superior.

[1]Survey of roadway from Sault Ste. Marie east-ward along the Lake Superior coast, Upper Canada Surveys, 1860-1866; on file with Ontario Department of Lands and Forests, Toronto.

Townships 31 and 30

The vein occurs in a breccia zone along a normal fault which strikes N32°W and dips 60°NE; the dip is almost vertical at surface. The breccia zone is exposed for 2,200 feet across the inland, although exposures are poor in the interior, especially in the swampy area (Fig. 14); the old trenches are almost completely filled by debris. At the south end of the inland, the southwest side of the vein is beneath Lake Superior. The zone locally bifurcates, contains unbrecciated horses of rhyolite, and, including small horses, ranges in width from 7 to 60 feet; the average width is 25 feet. Rhyolite fragments in the breccia are angular to rounded and range in size from a fraction of an inch to several feet. Fragments are cemented by calcite, hematite, quartz, barite, and manganite.

In addition to cementing breccia fragments, coarse-grained calcite also forms pods or lenses, which range in width from less than 1 inch to 15 feet and in length from 1 to 60 feet within, and parallel to, the breccia zone. In the lenses the calcite has a maximum grain size of three inches, varies in colour from white to grey, and locally has a pronounced colour layering parallel to the margins of the lenses. The grey colour is caused by disseminated hematite and locally manganite. The lenses appear to form 5 to 10 percent of the breccia zone and contain minor quartz and barite; rhyolite fragments are rare in the lenses.

Hematite cements brecciated rhyolite, forms disseminations and lenses in the calcite pods, locally coats rhyolite fragments which are then cemented by calcite, and locally appears to replace rhyolite. The hematite lenses in the calcite pods have an average width of 10 inches and are commonly less than 10 feet long; maximum dimensions are unknown. The hematite is commonly fine-grained and botryoidal.

Manganite, which is the only manganese-bearing mineral identified, is disseminated in, and forms lenses in the calcite pods. It locally cements breccia fragments, and locally coats rhyolite fragments which are then cemented by calcite. Manganite is fine-grained, locally botryoidal, and commonly intimately associated with, and locally appears to replace, hematite. Manganite-hematite lenses are as much as 6 feet wide although the average width is 1 to 2 inches.

Manganite and hematite are erratically distributed along the breccia zone but appear to form less than ten percent of the zone with hematite more abundant than manganite. The average manganese and iron content is not known. Several grab samples were collected by Harwood (1982, unpublished report) and by the author from richly mineralized parts of the zone (Fig. 14). The maximum manganese content was 15.1 percent in a sample which also contained 29.2 percent iron. Johnston and McCartney (1965) report a high-grade sample containing 36.3 percent manganese and 7.21 percent iron.

The sequence of mineral deposition in the breccia zone is complex, and the minerals were probably deposited from hydrothermal solutions during the Middle Keweenawan.

JORDAN ISLAND

On Jordan Island a breccia zone which strikes N15°W and dips 65°E is well exposed in rhyolite. The zone has a maximum width of 3 feet but averages 1.5 feet and contains about 20 percent quartz and calcite matrix. Hematite, which is locally botryoidal, forms lenses as much as 6 inches wide within the breccia zone. No manganese-bearing minerals were found.

ISLAND SOUTH OF JORDAN ISLAND

On the small island south of Jordan Island, a breccia zone which strikes N10°W and ranges in width from less than 1 inch to 4 feet is well exposed in rhyolite. The breccia matrix is commonly quartz and coarse-grained calcite. Within, and parallel to, the breccia zone are lenses of quartz and calcite as much as 0.5 inch wide, and lenses of hematite and manganite as much as 1 inch wide. A grab sample collected by the author from a manganite-rich part of the zone gave upon assay 3.31 percent manganese and 11.79 percent iron.

PANTAGRUEL BAY

Old reports provided by Algoma Ore Properties Limited describe a calcite-hematite vein in basalt on the northeast shore of Pantagruel Bay. This vein was trenched in 1910 and is reported to be at least 10 feet wide and to extend at least 1 mile inland along the contact between basalt and the Ryan Migmatite. A sample collected from this vein is said to contain 7.2 percent iron and 0.18 percent manganese.

The author found a 3-foot wide calcite vein filling a breccia zone in basalt on the shore of the bay. The vein strikes N.85°W but was not traced inland.

CONCLUSIONS

Calcite-quartz veins are common in the Keweenawan sequence (p.44), but breccia zones in which breccia fragments are more abundant than calcite and quartz matrix are common only in the rhyolite. During faulting the rhyolite probably brecciated more readily than the basalt.

In addition to manganiferous breccia zones, many narrow, north-northwest-trending, manganese-free breccia zones are present in the rhyolite, and other manganiferous veins probably occur beneath Lake Superior. Concentrations of manganese appear to be restricted to breccia zones in rhyolite, and thus the depth to which mineralization extends is controlled by the thickness of the rhyolite. On Devil's Warehouse Island the rhyolite has a minimum thickness of 350 feet.

IRON

In the map-area, concentrations of iron are present in metamorphosed iron formation and along some Keweenawan or post-Keweenawan faults. Iron concentrations may occur in the Gamitagama Lake Complex.

METAMORPHOSED IRON FORMATION

The metamorphosed iron formation units have been described previously. Magnetite is the dominant iron-bearing mineral; siderite, hematite, and iron silicates are rare.

Although these units are as much as 350 feet thick, the iron content is highly

variable. Some of the units appear to contain less than fifteen percent iron and would be ferruginous metachert and ferruginous metagraywacke rather than metamorphosed iron formation. Metamorphosed iron formation in the metavolcanic sequence appears to have a higher iron content than metamorphosed iron formation in the metasedimentary sequence.

The grain size of iron formation increases with increasing metamorphic grade, and coarse-grained iron formation is easier to beneficiate than fine-grained iron formation (Gross 1961). The thick iron formation units in the metavolcanics (p.16) were metamorphosed only to the lower part of the greenschist facies and are thus very fine-grained. The coarsest-grained, metamorphosed iron formation in metavolcanics is a 30 to 60-foot thick unit west of Red Rock Lake in Township 30, Range 20. It was metamorphosed to the uppermost part of the greenschist facies and grain size is 0.2 millimetres; the average iron content is probably greater than twenty percent.

IRON ALONG KEWEENAWAN OR POST-KEWEENAWAN FAULTS

Hematite is associated with manganite in calcite-cemented breccia zones in Keweenawan rhyolite in the Ryan Mineral Location (p.79, 80). The combined hematite-manganite content of the largest vein on Devil's Warehouse Island is less than ten percent.

Brecciated metasediments along a northwest-trending fault near the mouth of the Red Rock River in Township 31, Range 20 are cemented by quartz and hematite (Coleman 1906, p.179); the fault cuts Keweenawan rhyolite at the mouth of the river. The breccia zone has a maximum width of five feet and, unlike other fault zones in the map-area, commonly forms a low ridge. The hematite content appears to be less than ten percent.

Iron and Titanium

Gabbro and clinopyroxene diorite of the Gamitagama Lake Complex have an average content of 3.5 percent iron-titanium oxide; ilmeno-magnetite is commonly more abundant than hemo-ilmenite, especially in the gabbro. One gabbro sample contains 9.3 percent ilmeno-magnetite and 1.0 percent hemo-ilmenite. Biotite-hornblende diorite locally contains as much as 9.3 percent iron-titanium oxide with hemo-ilmenite commonly more abundant than ilmeno-magnetite. The maximum observed iron-titanium oxide concentration in the complex is in tiny recrystallite lenses in andesine anorthosite north of Flora Lake; the lenses are 1 to 12 inches long, and 1 to 3 inches thick and contain 8.5 percent ilmeno-magnetite and 3.5 percent hemo-ilmenite.

In gabbro and diorite, magnetite invariably contains ilmenite in trellis and locally sandwich intergrowths (Buddington and Balsley 1961) which form as much as twenty percent of the magnetite grains. Discrete ilmenite grains contain as much as ten percent exsolved hematite in tiny, oriented lenses; exsolved rutile(?) is present in both discrete ilmenite grains and in ilmenite intergrowths in magnetite. Discrete primary hematite grains are rare.

Larger concentrations of iron-titanium oxide might be discovered by detailed exploration of the complex. A strong magnetic anomaly over biotite-hornblende diorite in Township 29, Range 19 was reported to the author by a local resident.

Radioactivity

Lang (1952, p.134) and Lang *et al.* (1962, p.281) reported a radioactive mineral occurrence near the Red Rock River in Township 31, Range 20. Radioactivity as much as eight times background was measured over a 50-yard by 200-yard area underlain by red granitic rocks. The occurrence was not found by the author but is probably in the granitic phase of the Ryan Migmatite.

Agate

Rare agate amygdules as much as one inch in diameter are present in the Middle Keweenawan basalt, and, because the agate amygdules are resistant to weathering, agates were concentrated in the conglomerate members. The best collecting sites for agate are along Recent beaches adjacent to Keweenawan conglomerate.

Fluorite

Bigsby (1824b; see also Wilson 1939) reported purple and green fluorite in association with calcite in amygdaloidal trap three miles east of Cape Gargantua. In another paper, Bigsby (1824a) mentioned purple and green fluorite in association with calcite in rhyolite at the mouth of the Red Rock River in Township 31, Range 20.

The first description is incorrect because no Keweenawan basalt is found near the locality described. The author did not find any fluorite in the Keweenawan rhyolite at the second locality.

Sand and Gravel

The distribution of Pleistocene and Recent sand and gravel deposits is shown in Figure 8[1]. During construction of Highway 17, thirteen gravel pits were opened in these deposits adjacent to the highway (see Maps 2168 and 2180). In most parts of the area there is enough sand and gravel to meet future construction or mining needs.

[1]Figure 8 is on Chart A, back pocket.

Townships 31 and 30

Assessment of Mineral Potential

The Provincial Parks Act currently prohibits prospecting and staking in the map-area. Thus, the following assessment of the mineral potential of the area will not be useful unless current regulations are changed.

Most of the larger concentrations of economically important elements occur in, or are associated with, the Gamitagama Lake Complex: (1) copper-nickel concentrations appear to be restricted to the southern part of the pyroxene gabbro and diorite core of the complex (Fig. 11); (2) copper is locally concentrated near fault zones in the contact zones of the complex, especially in mafic meta-volcanics; and (3) gold-bearing quartz veins were found in sheared, porphyritic, quartz monzonite dikes within pyroxene gabbro and diorite. The entire complex, especially the mafic phases and fault zones in the contact zones, should be subjected to detailed exploration.

Metamorphosed iron formation commonly has a low but variable iron content and low metamorphic grade. Consequently, even in those parts of the iron formation with a relatively high iron content, beneficiation would probably be difficult because of the very fine grain size. The only exception is a small unit west of Red Rock Lake in Township 30, Range 20.

The Keweenawan volcanic sequence and diabase dikes contain small concentrations of copper, manganese, and iron.

Mineralized Keweenawan breccia zones similar to those in the Batchawana area (Giblin 1968) may occur in the map-area. Many faults in the map-area have Keweenawan or later movement, and the chalcopyrite-bearing breccia along the Buckshot Creek fault in Township 31, Range 19 may be Keweenawan in age. Similar zones may occur along other faults but could have easily been missed during the geological survey because fault zones are poorly exposed. Brecciated pegmatic granite within the Biddlehead River Quartz Monzonite east of the south end of Stewart Lake in Township 30, Range 19 may also be Keweenawan in age; no mineralization was observed in the breccia.

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APPENDIX

Nomenclature

ROCK NOMENCLATURE

The plutonic rock classification used in this report is shown in Table 11. This classification was developed to emphasize the common occurrence in Ontario of oligoclase-bearing, potassic feldspar-poor granitic rocks (trondhjemite) and the rarity of granitic rocks containing primary albite. Most rock names are used in the sense intended by the original authors. Norite is a gabbro in which orthopyroxene is more abundant than clinopyroxene; anorthosite and andesine anorthosite are respectively gabbro and diorite which contain less than ten percent mafic minerals.

Volcanic terminology has been restricted to rhyolite, trachyte, rhyodacite, dacite, andesite, and basalt which approximately correspond to granite, syenite, granodiorite, trondhjemite plus tonalite, diorite, and gabbro of the plutonic classification. In the field, colour index was used to subdivide metavolcanic rocks into felsic and mafic groups: felsic metavolcanics comprise rhyolite, rare trachyte, rhyodacite, and some dacite; mafic metavolcanics comprise basalt, andesite, and some dacite. Further subdivision of these two groups can sometimes be made on the basis of petrography.

Sandstone and metasandstone have been classified according to Pettijohn (1957). Generally metamorphic recrystallization destroys primary rock fragments and detrital matrix, which are essential criteria in Pettijohn's classification, at a low metamorphic grade. However, when relatively unsheared samples were selected, the classification was found to be applicable to most of the greenschist facies part of the area.

DIABASE TEXTURE

In diabase there is commonly a wide range in texture, but the texture can usually be described as ophitic, subophitic, isogranular, intergranular, or intermediate between two of these types (Oppenheim 1964).

Ophitic Texture: pyroxene appears in thin section as optically continuous areas which *completely* enclose a number of plagioclase laths. The average length of the plagioclase throughout the rock is not greater than the average length of the pyroxene areas (Clark 1952, p.71).

Subophitic Texture: pyroxene appears in thin section as optically continuous areas which only *partly* enclose a number of plagioclase laths. The average length of the plagioclase is greater than the average length of the pyroxene areas (Clark 1952, p.71).

Isogranular Texture: hypidiomorphic to idiomorphic pyroxene grains in the interstices between, and having the same order of size as plagioclase prisms (Oppenheim 1964, p.552).

In diabase dikes with this texture in the map-area, the pyroxene is commonly hypidiomorphic to allotriomorphic.

Table 11 | *Modal classification of non-feldspathoidal plutonic rocks*

Quartz	Potassic Feldspar / Total Feldspar	COMPOSITION OF PLAGIOCLASE An0-10	An10-30	An30-50	An50-100	MONOMINERALIC	LESS THAN 10% FELDSPAR
QUARTZ GREATER THAN 10%	>⅔	Potassic Granite					
	⅓-⅔	Sodic Granite	Quartz Monzonite	Calcic Quartz Monzonite			
	⅛-⅓		Granodiorite	Calcic Granodiorite			
	<⅛	Albite Granite	Trondhjemite	Tonalite	Quartz Gabbro		
		← GRANITIC ROCKS →					
QUARTZ LESS THAN 10%	>⅔	Potassic Syenite				Anorthosite	Peridotite
	⅓-⅔	Sodic Syenite	Monzonite		Calcic Monzonite	Hornblendite	
	⅛-⅓		Syenodiorite			Pyroxenite	
	<⅛	Albite Syenite	Diorite		Gabbro	Dunite	

Intergranular Texture: the angular interstices between the feldspars are occupied by ferromagnesian granules (Williams *et al.* 1955, p.22).

CHEMICAL ANALYSES

All chemical analyses were done by the Laboratory Branch, Ontario Department of Mines. Trace elements, MgO, TiO_2, and MnO were determined by emission spectrography; SiO_2, Al_2O_3, total iron, CaO, and K_2O by X-ray spectrography; and other oxides by chemical methods. All norms were calculated by the method of Barth (1962).

ROCK-STRATIGRAPHIC NOMENCLATURE

Formal names have not been applied to metavolcanic or metasedimentary formations because these formations can probably be traced northward to the Michipicoten area where some formations were previously defined (Goodwin 1962). Further work is necessary before correlations can be made with the Michipicoten area. Formal names have been given to several of the plutonic formations which are first described in this report.

TIME-STRATIGRAPHIC NOMENCLATURE

Using isotopic age determinations, Stockwell (1964) recently revised Precambrian, time-stratigraphic nomenclature, and he placed all pre-Keweenawan rocks in the map-area in the Archean (as shown on G.S.C. Map 4-1965). Except for the Keweenawan and younger systems, the author has not assigned rocks to time-stratigraphic units because no age determinations are available.

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